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Editor's Column

Although the JOURNAL is now receiving a substantial flow of article submissions, we are desirous of increasing the number and quality of articles received. This editorial is addressed to two types of "hold-outs," namely, you who have applied some principles of industrial engineeriing in a unique manner who would submit a write-up of same if it were not for your company's policies of secrecy on such subjects; you who have in mind something which you feel is worth writing about but, being pressed for time and not being necessarily fond of writing, hesitate to spend the hours required for proper presentation of the subject matter since you are unsure whether the JOURNAL is interested in publishing it.

To you in the first group we say, "Send it in." Since the JOURNAL is not a trade publication, we need not mention the name of your affiliation in connection with the article. We suggest that you who are in the second category jot down and send us the basic relevant aspects of the thing you have in mind. We will give it careful consideration, possibly offer a bit of counsel and will promptly tell you whether we think the subject matter falls within our criteria for publishable material. This preliminary review will tend to insure that you do not waste time writing something which we feel should not be published in the JOURNAL.

The JOURNAL is interested in publishing quality articles, describing application or research findings on the subjects of Time Study, Motion Study, Material Handling, Plant Layout, Incentives, Standard Costs, Engineering Statistics, Production Control, Engineering Economy, General Scientific Management, Budgets, Technical Report Writing, Job Evaluation and Merit Rating. The JOURNAL is also interested in inspirational articles reflecting on the advantages of sound industrial engineering. As a member of A.I.I.E. it is your professional duty to contribute, to the fullest of your capabilities, to industrial engineering's reservoir of knowledge.

THE INDUSTRIAL ENGINEER AND HIS FUTURE

By Dr. K. O. W. Sandberg

Manager, Industrial Engineering Dept., General Electric Co. Chemical Dept., Pittsfield, Mass.

Most young Industrial Engineers struggle with the problem of their future careers. Where will their present training lead them? What plans should they make to help fate along in the right direction? What happens to your career is a result of your analysis and plans, plus a bit of luck. You can give turn-of-events a quick twist by being ready for opportunities when they knock. More than this, you can help opportunities along by having your own 2-year plan, 5-year plan, 10-year plan, and 20-year plan.

It seems to me you have two basic questions to answer for yourself. First, you must decide whether you are a line man or a staff man. Very few of us by nature, are outstanding in both types of work. Secondly, you must decide whether or not you are a die-hard family-man or whether or not you are willing to accept traveling. The answers to these two questions are somewhat interrelated.

The nature of the staff man's work is review of the past, analysis of the present and planning for the future. In these fields of planning and audit, he receives considerable training from the colleges. His early experience is of the same character. He delights in details, in complete coverage of the problems in hand and in high precision of thinking. His attitude tends to make him a perfectionist.

The line man, on the other hand, is impatient with detail and perfection. He wants to get "on with the show" and tolerates very little planning and analytical review. There are some industrial engineers who have ambitions to get into line management and yet are really congenital staff men in their make-up. These men are really not fitted for line supervisory work at the moment. They are the kind of whom so much is spoken when it is said that the industrial engineer will never become the plant manager or factory superintendent. He is not a leader of men or today's events. Rather he sets the stage for tomorrow's events.

But the industrial engineer need not think therefore that his future is hopeless if he finds his own self-evaluation places him in the staff man category. Recent trends in larger organizations have been able to make a substantial place for industrial engineers in top echelons. There are well known companies in which there are a vice-president in charge of industrial engineering or a staff vice-president in charge of manufacturing (where consulting services available are essentially of industrial engineering character). Such jobs are slowly ascending to a well recognized place in the organization structures of larger companies.

I recommend therefore, that you consider a professional career in industrial engineering via the staff route if the latter is your inclination.

Today there are far-too-few really good professionals attached to staffs of line organizations. Some other few that exist are employed by consulting firms or universities because, up until just recently, there has been no other place to turn. Consulting firms, however, involve a great deal of travel. Some of this is minimized when employed within one company as part of staff's staff, which can be likened unto a consulting industrial engineering group although within a large organization. Yet even this involves some travel with today's trends of decentralized organization and separation of plants.

What then are your job opportunities as an industrial engineer? They can be in staff as well as in time-honored line. The custom of considering industrial engineering work as merely a stepping stone to line management need no longer be the case. However, there is no denying the wonderful preparation so obtained.

The world is made of many temperaments. Industrial Engineering is now beginning to find acceptance at high levels for the temperament which in the past has been considered a failure at such levels. In fact, the tables now seem reversed. Truly, it is the real professional industrial engineer who selects to make staff industrial engineering his full career. It is from him that future advances in scientific management will spring. In many respects, nothing could be more satisfying than that this should take place. America needs increased productivity and lower overhead. Only the professional career man is in a position to make the advanced contributions which are necessary to the fulfillment of these objectives. Thus you face in your decisions both a challenge and an opportunity.

WAGE INCENTIVES IN A FOUNDRY

By Clifford J. Pruet

Manager, Standards Department, McWane Cast Iron Pipe Company, Birmingham ,Alabama

At McWane Cast Iron Pipe Company, where high pressure pipe and fittings are produced for water and gas, both the deLavaud centrifugal process, which entails the use of permanent metal molds, and the sand cast methods are used in making pipe. Fittings are made in sand molds, either on jolt-squeeze machines or on the floor.

We have had a wage incentive plan since 1937. It is a standard plan which provides for a 1% increase in pay for each 1% increase in production above standard. The incentive application covers direct, indirect, and maintenance workers and all levels of supervision. Approximately 450 employees are covered by the plan.

The wage incentive plan was installed by an outside consulting engineering firm who also trained a staff to maintain the plan. Before the work was started, the purpose of the plan and the expected benefits and results were explained to the foremen, the Union Committee and the operators. This was done in groups, by departments and individually. Explaining the incentive plan is a function that never ends.

The foremen and the control features are the key to the success of our incentive plan. To be assured the incentive plan would function properly, the foremen were given a thorough understanding of the system, and the part they must play in the administration of the plan. To make this possible, the management gave the foremen any special training or instruction required. This was done individually and in groups. The importance of special training and instruction for the foremen cannot be overstressed, as they must be taught new concepts, procedures and techniques. If the foremen do not understand the principles of motion and time study, job evaluation, and wage incentives, the plan cannot be expected to give maximum results.

High productivity is the keystone of low unit cost and a higher standard of living. One of the best means of obtaining high productivity is through equitable wage incentives. Any successful wage incentive plan must be based upon sound principles, proper administration and maintenance, and must be understood by those who participate.

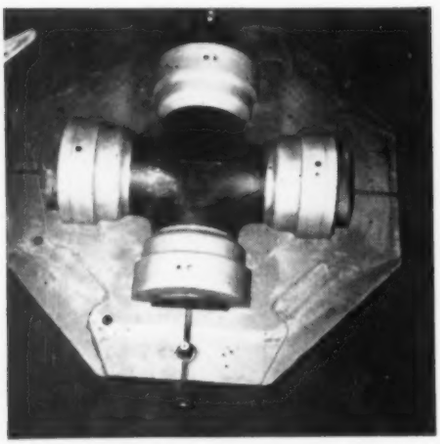
Accordingly, the purpose of our wage incentive plan is to obtain higher production, better quality, higher wages, better employer-employee relations, lower unit cost and control over operations.

For maximum results the man on the job must believe in the fairness of the performance standards, base rates, and the policies of management. There must be mutual confidence, respect and understanding. Equitable base rates are established by job evaluation and base rates are guaranteed regardless of individual or group performance. Proper base rates should be established before production standard time values are applied.

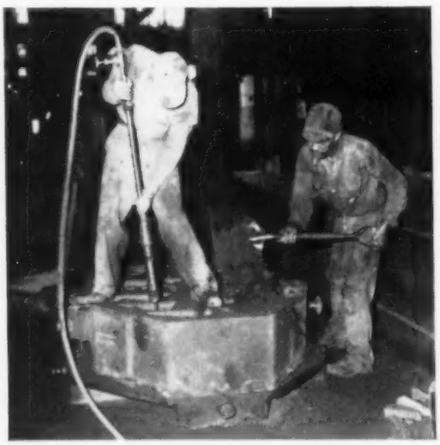
We have found that individual incentive is generally more effective than group incentive. Normally, the larger the group, the less effective the incentive plan will be. Where group incentive is used, the output of the best operators is usually about the same as that of the average. The reason for this is that the best operators are not paid relative to their individual skill and ability, but on the group average. Conditions and type of work performed will determine the type of incentive best suited for a specific operation.

The basic principles for a successful wage incentive plan are about the same in a foundry as in other industries. However, each industry has individual problems and conditions which must be standardized and controlled before an effective incentive installation can be made. Some of the variables and conditions which have to be controlled in the foundry are: Type of sand to be used, grain size and distribution, water and clay content, oil and binders, permeability, strength, durability, expansion, flowability, refractoriness, etc.

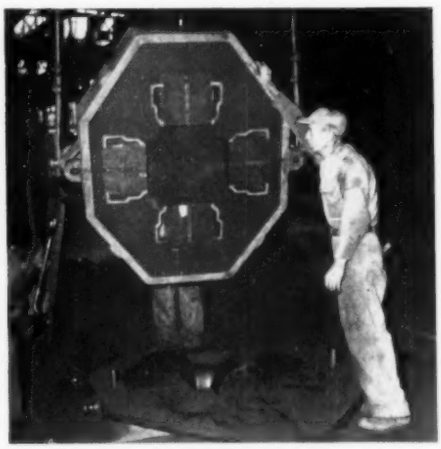
Our foremen are the most logical group to explain the incentive plan to the operators, as they are in closer contact with the operators than other members of management. The foremen



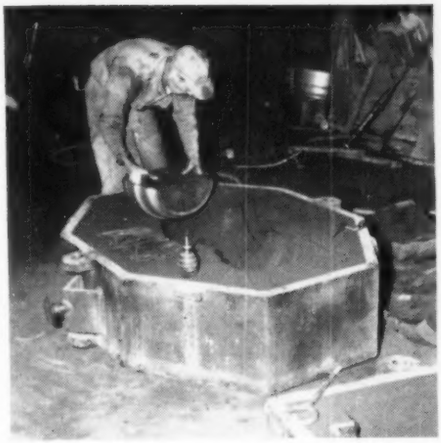
Pattern & Pattern Plate for 10"x10" All Bell Cross, Open Bell.



Step No. 1—Molder ramming sand between flask bars of drag flask with pneumatic rammer while helper shovels sand in flask.

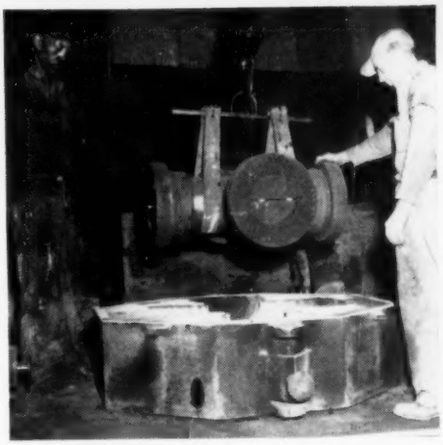


Step No. 2—Lifting drag flask from pattern plate by crane and turning flask over.



Step No. 3—Molder drawing bell pattern from drag mold.

Step No. 4—Molder patching and smoothing up sand in bells.



Step No. 5—Molder and helper setting dry sand core in mold with crane.

teach new methods and procedures to the operators and work with them until they attain a satisfactory level of performance. They also explain to the employees the necessity of improving methods, procedures, etc., which will in turn permit the company to maintain a competitive position in the industry.

The application of incentive standards is preceded by any possible improvements in design, equipment, methods, scheduling and materials handling, etc. Standard procedures are established to stabilize performance standards and earnings.

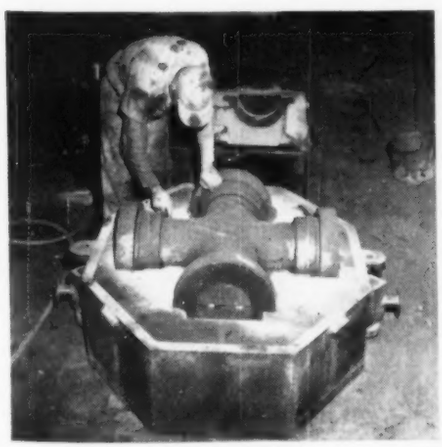
The desired quality and finish is determined before the production standard is established. Quality is not allowed to deteriorate, thus workers are not paid premium for producing scrap or faulty work. Quality has actually increased with increased production, because of the fact that the operators have a strong incentive to improve their skill. The higher the skill, the better the quality. As a result of the incentive urge, some operators develop superskill. The time taken to train new workers is greatly decreased by our wage incentive. The desire to learn is increased in proportion to the increase in take-home pay. We find almost invariably that when operators are assigned work not covered by the incentive plan, they request that time studies be made, as they prefer to work on measured operations rather than on "day work."

The first step in applying incentive and production standards to a job is to contact the department head and the foreman and explain the purpose of the study and the manner in which it is to be conducted as well as to discuss problems concerning methods, tools, equipment, materials handling, etc.

The second step is for the foreman and time study man to contact the operator on the job and have the foreman explain the purpose of the study to him. This will give each party concerned the opportunity to ask questions and will result in better overall understanding.

The time study man then proceeds to study the job. The performance of the operator is recorded for each element of the cycle while the study is in progress. The length of the study and number of cycles observed will depend upon the nature of the operation. When the study is complete and all necessary related information recorded, the time study man computes the normal time for a qualified operator to perform the operation. To accomplish this, a performance rating is applied to each element in the cycle.

(Continued on Page 26)



Step No. 6—Molder touches up core and edges of mold before setting cope mold on.

Step No. 7—Molder and helper guide cope flask down on drag with guide pins.

Step No. 8—Molder and helper clamp cope and drag together.

A TEST OF OBJECTIVE RATING IN ENGLAND

By D. J. Desmond

Tube Investments Research Fellow, Dept. of Engr. Prod., Univ. of Birmingham, England.

The prolonged visit of Professor M. E. Mundel to the University of Birmingham has aroused considerable interest in his method of objective rating.[1] A session was therefore arranged recently by the Work Measurement Research Unit to investigate the quality of the time study ratings which can be obtained by practising time study engineers when they use the method for the first time.

All the time study engineers who attended the rating sessions held in Birmingham by the Work Measurement Research Unit during the National Survey were invited to take part and altogether 79 engineers participated in the experiment.

All of the engineers were first shown 15 scenes of three of the operations of the SAM films on Performance Rating recently released to the public in USA. These films had already been rated by the participating engineers (and they had examined their results) during the British National Survey, but this time they were projected in the form of loops instead of as a continuous film. The three operations used were:

D Dink tile squares
V Colate papers
R Pack cans

as these were considered to give a good representation of typical industrial operations. They were shown the trailer first and given a full explanation of the operations and the loops were then rated, using their own familiar rating scale. These ratings were recorded on a form which was then collected so that the figures could be used as a standard for the later part of the experiment. The group was then split into two parts at random, one of which acted as a control while the other tried out the objective rating method.

The control group went into another room where they re-rated the same loops but now they were given about three times as long to decide upon their ratings. These figures were recorded on another form which was subsequently collected but not until the engineers had made a graphical analylsis of their results.

[1]M. E. Mundel, "Motion and Time Study," Prentice-Hall, New York, 1950, pp. 319-365.

The objective group were given a brief account of the multi-image loop which was then projected at the side of the operation to be rated and the engineers were asked to record which image of the multi-image loop corresponded in pace, i.e., initial acceleration, to that of the operation. They were not given any numerical values as to the ratings of the images except that they were informed that the numbers of the images corresponded to different paces and that there was a steady increase in pace as the image number increased. In case it might be thought that some scenes were being performed at a pace outside the range of the multi-image loop, they were told the percentage change in pace along the top and bottom rows and they could record a value as being a percentage above the maximum or below the minimum if they considered that the pace came outside that range. After recording all their ratings the two parts of the group reassembled and they were shown how to analyze their results graphically in order to see what they had achieved. All the forms were then collected for more accurate analysis to determine the effect of the multi-image loop.

The initial analysis of the data was to determine two matched groups so that an objective comparison could be made of the two methods. It was considered that 20 engineers in each group would be sufficient for this purpose and as 55 of the engineers used the 60/80 rating scale, the analysis was confined to those engineers. The Reciprate method of analysis[2] was employed and three characteristics of each study were calculated to give suitable measures of their quality. These are:

1 Normal Time, i.e., a measure of the concept of performance
2 Flatness, i.e., a measure of the inability to appreciate proportional changes in speed
3 Inconsistency, i.e., a measure of the random errors of rating including the inability to appreciate the same speed when seen on more than one occasion.

[2]A brief account of the method was published in "Engineering," Vol. 170 October, 1950, and a fuller description will shortly be published by the Royal Statistical Society in the Proceding of a Conference on Scientific Method held in Sheffield, 1950, under the title of "The Statistical Approach to Time Study."

These matched groups were obtained by the analysis of the original ratings and the results obtained are here referred to as "standard." Firstly each operation was considered separately and they then were combined to give a more precise estimate of the quality of the ratings. The first test to be applied with the statistical test of uniformity of inconsistency and it was found that one engineer gave rise to a lack of homogeneity so he was rejected from the 55. The separate flatnesses were then calculated and set out as a 3x54 table and it was again found that the data were hetrogeneous. Homogeneity was established by the elimination of another four engineers whose average flatness was inconsistent with the remainder. This left 50 engineers whose concept of normal performance was then examined. At this stage it was found that 24 of them were in the control group while 26 took part in the objective rating. Twenty engineers were then chosen from each group, eliminating the extreme values as far as possible, and they were selected in such a manner that the standard deviations of the normal times among the engineers in each group were in agreement to within 0.01%. These were then considered to be the matched groups and as a safeguard the characteristics of both groups were compared for each operation to establish that there was not any significant difference between them. The same characteristics were then calculated from the ratings they recorded at the second projection of the loops.

Results

The following tables show the changes in quality produced by the second showings. An improvement in quality will in each case be shown by a reduction in the numerical value of the characteristics but no difference should be considered to have been proved unless it is statistically significant. Any unmarked figure represents no significant change, that is, the difference could be attributed entirely to chance, bearing in mind the random variation among the figures. The degree of significance is indicated by the

number of asterisks according to the following plan:

*barely significant; change possible
**significant; change probable
***highly significant; change almost certain

Flatness

The differences in percentage flatness from the standard are given in the following table. An improvement in quality of rating is shown by a negative change.

CONTROL

Operation	*Mean Change*	*Standard Error*
D	— 3.62	5.89
V	+ 2.14	6.22
R	—14.70*	6.22
all	— 5.37	3.92

OBJECTIVE

Operation	*Mean Change*	*Standard Error*
D	— 7.65	5.45
V	+ 9.70	7.47
R	—25.70***	7.28
all	— 7.91*	3.62

Inconsistency

The following table gives a comparison in the inconsistencies of single ratings expressed as a percentage. Low values correspond to high quality.

CONTROL

Operation	*Standard*	*Control*
D	11.9	10.9
V	11.6	9.4*
R	11.6	9.1*
all	11.7	9.8**

OBJECTIVE

Operation	*Standard*	*Control*
D	11.6	9.8
V	10.4	11.7
R	12.7	9.8*
all	11.7	10.5

Concept of Normal Performance

Since there is no absolute standard of performance for any of the operations studied in this test, the best measure of the uniformity of the concept of normal is the standard deviation of the normal times established by the engineers in the groups. This is conveniently expressed as a percentage and the following table records the results obtained in this form. Low values correspond to the highest degree of uniformity and give a measure of the "sameness" of the concept of normal. By providing an objective comparison, the multi-image loop would be expected to reduce the variation among the engineers.

CONTROL

Operation	*Standard*	*Control*
D	6.2	7.4
V	8.1	9.5
R	5.2	6.3
all	8.6	11.2

OBJECTIVE

Operation	*Standard*	*Control*
D	7.2	7.6
V	6.7	14.0**
R	6.0	6.6
all	8.6	12.4

Conclusions

It can be seen from the above tables that most of the differences obtained were not significant although the objective method of rating did show an improvement in flatness which was not produced merely by the second showing and a longer period of time in which to make a decision. However, the difference between the two results was not significant. On the other hand, the control produced a significant improvement in self-consistency which was not obtained by the objective group. Again the difference between the two groups could have occurred by chance.

Examination of the differences among the engineers' concept of normal performance shows a deterioration in the case of one operation by the objective group and this difference was significantly worse than the difference obtained by the control group. However, this was only just significant and it was not confirmed by any of the other speculation.

Taking the experiment as a whole, it may be deduced that the first attempt to use the multi-image loop as an aid to rating produced neither an improvement nor a deterioration. In the author's opinion, taking the background of the experiment into consideration, there is a fairly good case for continuing experimentation with the multi-image loop to examine whether an improvement is possible to be achieved when the engineers are more familiar with its use.

Numerical Methods in Engineering

By Mario S. Salvadori

—a book review by James R. Garrett, Asst. Prof., Department of Mathematics, Georgia Institute of Technology.

The objective here is to direct attention to a worthwhile publication without presenting theoretical complications. Anyone seeking to utilize the volume must necessarily examine it in detail.

The five chapters of this book present interesting and useful aspects of certain numerical methods which are applicable in the solution of technical problems encountered by student and scientist. Particular care is given to the methods likely to produce results through machine computation where less highly trained personnel can be utilized. This very feature will appeal to persons involved in industry. The book has the added feature that it assumes only calculus and a few facts from differential equations.

The solutions of algebraic and transcendental equations in Chapter I are gotten by more or less routine and familiar methods. The four procedures for solving systems of simultaneous linear equations are less familiar generally. The above methods are adapted to slide rule and electric (as well as electronic) calculators and yield accuracy of 5 to 10 significant figures and admit problems involving 40 to 100 simultaneous linear equations. Many exercises which are helpful in mastering techniques and suggesting applications are included.

The elementary theory of finite differences and its applications to many problems is considered in Chapter II. Differential equations of considerable difficulty often arise from various technical sources, and their solutions many times are best obtained from approximate methods. These methods which give values of the unknown integral at known points on its interval of definition lead naturally to difference concepts. Ordinarily solutions deduced in this manner fail to yield general physical laws where initial value or boundary value problems are concerned.

The numerical integration of initial value problems considered in Chapter III relate to nth order differential equa-

(Continued on Page 26)

MAINTAINING CONSISTENT STANDARDS

By Harvey Gittler

Industrial Engineer, Yonkers, N. Y.

Every plant is faced with the problem of setting consistent standards. The demand for consistent standards comes from all levels of management, from the workers, and from the union. The backbone of consistent standards is consistent ratings. Regardless of the rating or leveling technique used, time study engineers, within any given plant, must be able to rate operators within well defined limits and thus come up with satisfactory standards.

Present practice is to use films to teach the rating concept and to develop consistency among the time study personnel. Usually movies of various operations such as card dealing, walking, and factory jobs are shown, and the time study engineers are asked to rate the operator performing a particular job. Several scenes of the operation are shown and each scene shows a different level of performance. In viewing such films, the time study man will record his ratings and later compare his ratings with the known or true ratings supplied with the films. The ratings can be plotted on an X-Y graph with the X-axis giving the true rating and the Y-axis giving the observer's rating. If possible, a straight line is drawn through the points plotted and this is compared with a line that passes through the origin at an angle of 45°. This is the line that would occur if the observer had rated each operator 100% correctly.

Such films are very useful in teaching the rating concept, but are lacking in help they can give the Industrial Engineering department in maintaining consistent ratings. Films often cover operations that are not similar to any operations within a particular plant. At a result, time study engineers are learning to become consistent in rating operations that they never have occasion to observe. In addition, it is often difficult to find films that cover the type of operations you are interested in rating.

For those plants that rate by element where possible, films present another problem. Training films offer an opportunity to rate only the entire operation. Thus, you are training personnel in practices of which you do not approve.

Another point to consider is the transposition lose. A transposition lose is the error in rating that may occur when an engineer goes from viewing and rating operations on films to viewing and rating operations on the factory floor. Actually, the observer has to make a mental adjustment which might introduce a source of error—an error due to a mental transposition.

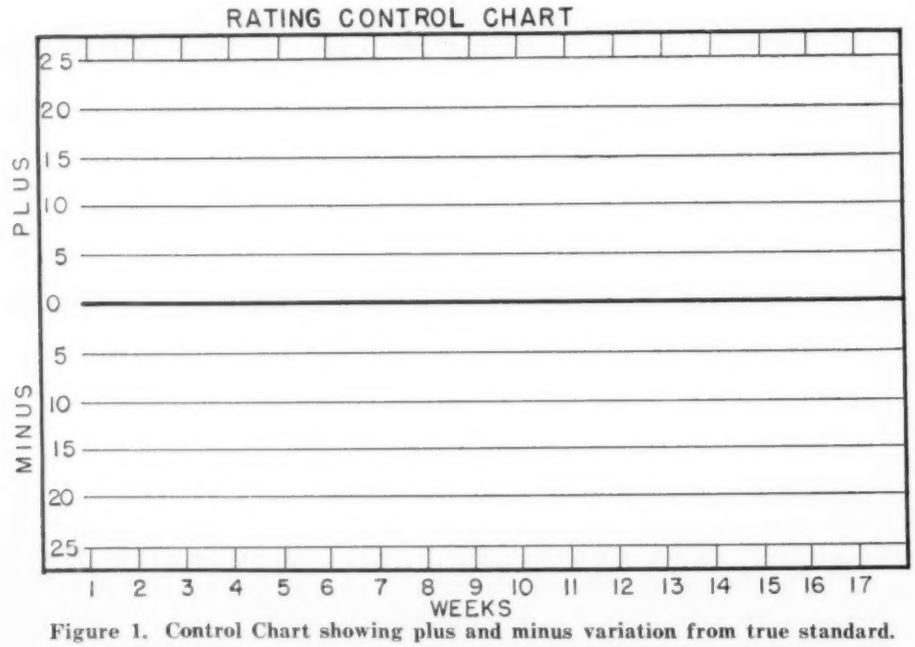


Figure 1. Control Chart showing plus and minus variation from true standard.

You never run out of operations in the factory that have to be studied or that can be restudied. But it is easy to exhaust a supply of films. You have operators who work at a slow pace and others who work at a fast pace, usually the entire range of performances are covered. In films, you are limited to the production paces of the operators shown. Add to this the fact that the time study personnel can become familiar with the true ratings of the film operations but rarely will they become familiar with the standard time for one particular element of an operation, and you have another reason why your plant offers a wonderful opportunity for you to maintain consistent ratings.

Does your plant have standards which have been in operation and have shown themselves to be correct? Why not use these operations to help you maintain consistent ratings? Coupled with a chart, you have a means of measuring each time study engineer's progress.

The plan is simple. Once a week, or at any time interval you may wish, a time study man is sent out to time a particular *element* of a particular job. He proceeds to take a time study of just this one element in accordance with the standard practices of your plant. He takes the number of readings that you would require to set a standard and he rates the element as he does in the normal time study procedure. Then he returns to his desk.

Here he develops a time value and applies his rating. Then you tell the engineer what allowances were used in setting the standard. These allowances are applied according to the procedure you have set up. The result: you now have a new standard, which is called the *test standard* to compare with the accepted or *true* standard.

How do you compare these standards? Just follow this simple equation:

Test Standard — True Standard ÷ True Standard X 100 = % Variation from True Standard.

If the answer is a negative value, the rating has been "tight." This means the observer rated the operator below his actual performance level. If the

answer is a positive value, the rating has been "loose." This means the observer rated the operator above his actual performance level.

How does this help you maintain consistent ratings? Plot the points on a Control Chart shown in Figure 1. Each engineer maintains his own chart and is able to see whether he is making any progress. Coupled with the chart, keep diaries explaining the element studied and giving the calculations for the points. Thus, it becomes possible to tell whether an engineer is loose or tight in his rating, whether he overrates or underrates heavy or light work, or whether he rates fast workers below their actual performance level and slow workers above their actual performance level (called "Conservatism").

These charts are interesting to follow. Figure 2 shows an engineer who is consistently tight in his ratings while Figure 3 shows the opposite, an engineer who is consistently loose. You may have charts which have positive and negative values. Working with the chart and the diary, you can often get to the core of the rating problem very quickly.

Naturally, this type of control mechanism has several disadvantages. This type of review may take a little longer than films. Using films, you can usually have a "rating session" which is not possible with this technique. Then too, you must have some good standards in existence if you want to use this technique to help maintain consistent ratings.

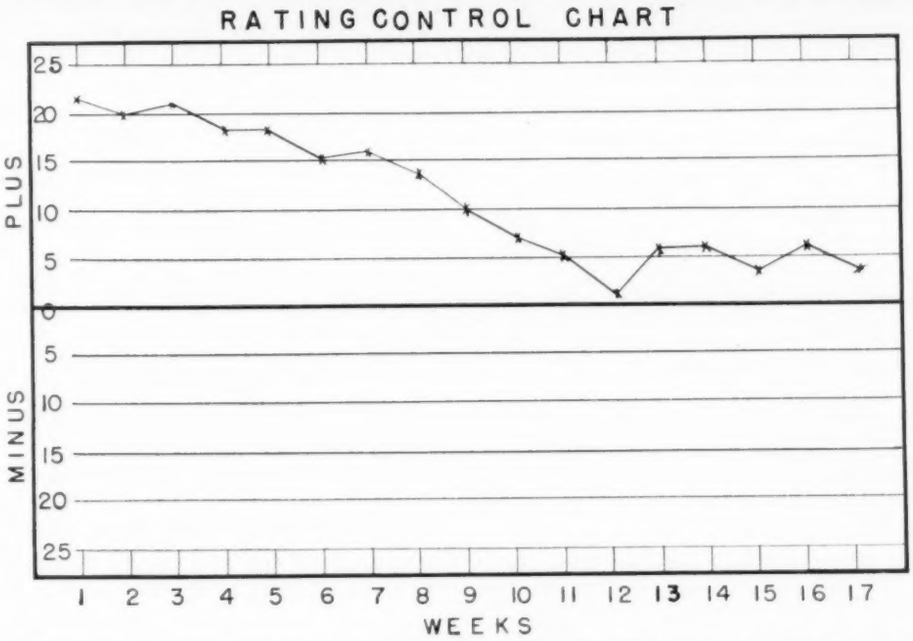


Figure 3. Ratings that result in loose test standards. This comes about by rating the operator above his true level of performance. As a result, the answer is positive because the test standard is greater than the true standard.

A control chart should show variation in only one variable. Therefore, it is right to ask whether only one variable is being measured with this Rating Control Chart. Does not the time study man's ability to read a stop watch or even handle a stop watch creep in as an additional variable? The answer is yes—if the time study man is going through the initial stages of training. However, you are not interested in the problem of consistent ratings during the initial stages of training. When the time study man is properly trained and knows how to take a time study, the problem of consistent ratings is of paramount importance. Under these conditions, the Rating Control Charts measure only variation in ratings.

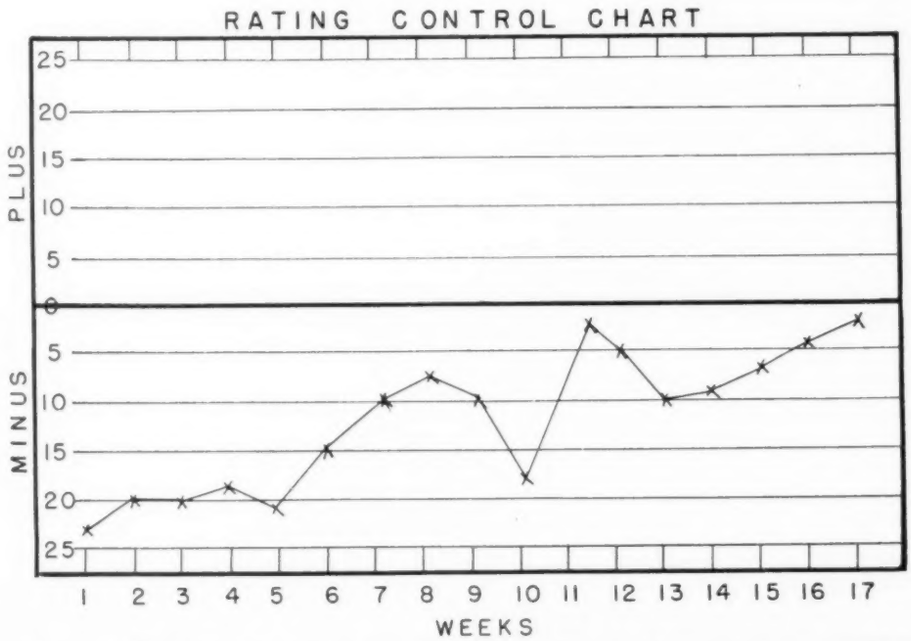


Figure 2. Ratings that result in tight test standards. This comes about by rating the operator below his true level of performance. As a result, the answer is negative because the test standard is less than the true standard.

The advantages of this technique are many. First, you have a positive means of measuring the variation in rating of each individual engineer not from someone else's rating or films, but from tried and tested ratings within your own plant. When new personnel join your department, it is easy to show them what you consider 100% performance and in a short time you can tell just where they stand in relation to practice within your plant. The variation from true standard can be plotted and you can see how the engineer is progressing. Often, the rating process requires a mental adjustment to the concepts existent within your plant. With the charts, you can see this adjustment taking place.

If you work with well intentioned union time study stewards, they are sure to like the idea of using operations and operators within your plant to assist in maintaining consistent standards.

Along with these advantages, the disadvantages that go with films are eliminated. This does not imply that films are eliminated. They are still of value for training and instructing.

A NEW SELECTION ASSESSMENT TECHNIQUE

By Warren Lamb

Patton-Lawrence, Ltd., Manchester, England.

The problem of selecting the right man for the job has been given especial recognition during the last few years. This article assumes that the dangers of haphazard appointment to jobs, particularly at the managerial level, are commonly realized and that any objective method which can point to a high measure of success will be enthusiastically welcomed.

During the last fifteen years a revolutionary technique has been developed in England which has more than fifty years of research behind it. Whilst it is based upon a psychology of movement it is quite independent of the concepts upon which industrial psychology has, up to now, been created and the technique does not employ any testing.

Some hundreds of assessments have been made in England at all levels of industry by the firm of management consultants who promote the technique. Although no claim of infallibility can be made for a technique concerned with man's study of his fellow men, no assessment has yet failed to get so close to the truth as to be depended on for helping both the firm and the chosen candidate.

Such an achievement is bound to have far reaching effects. The form of assessment is not only performing a notable service in finding the most suitable of a number of candidates but provides information which the employer actively uses in his treatment of the worker or subordinate.

Capacities relating to the job are discerned as to:—

a. Those which can be immediately utilised in the carrying out of the job.
b. Those which can be developed by training and practice to become an active capacity.
c. Those which are to all intents and purposes lacking and will therefore require supervision or the provision of specialist advice or delegation of duties.

Thus employers are told, briefly, "Exploit these capacities; it's your duty (to the firm and to the man) to see that those are developed; so far as these are important for the job you must make sure that adequate provision is made."

Employers have responded to this advice, simply expressed in a business-like way and in a form which is concentrated upon the needs of the job under review. Further information as to how the man uses his capacities is given in a section termed "General Aptitudes" and here advice is also given how best to develop the latent capacities—whether through training, increasing responsibilities, gradually specialising the job requirements in a particular direction, and so on.

Most significant in this new method is the link actively preserved between assessment and treatment. It is felt that one without the other is like a doctor diagnosing a patient without giving any treatment and the assessors try to follow up each case. Their work is done in conjunction with a complete management consultancy service which includes a training establishment.

The technique is used also in collaboration with a business survey for which the senior staff and a cross-section of the work people are assessed for the purpose of making the best use and development of the abilities available.

To understand something of the growth of this fascinating work it is necessary to go back more than fifty years to the first investigations made by Rudolf Laban into the observation and meaning of human effort. His researches took him all over the world and into many spheres of activity. The results which he has been able to present to the world have greatly influenced contemporary research over a very broad field.

The development of the industrial selection technique has been from the concept that people cannot help but reveal themselves through the movements their body performs. Each phrase of movement, whether of the whole body or of an eyebrow, reveals the inner effort of the person. It is possible, by acting, to use different movements to those normally employed, but impossible to alter the habits in phrasing one's movements. It is in the quality of the phrasing of bodily movements that no-one can disguise his individuality.

Laban applied himself to the task of devising a form of notation which a trained observer could use quickly to record the movements of a candidate as they were happening. The record thus obtained would show the phrasing of efforts habitual to the man or woman observed. It then had to be discovered how to analyze and assess these efforts in order to reach conclusions to be expressed in words, and how much observation would be necessary.

The latter part of the research was done in conjunction with F. C. Lawrence, a management consultant, and their achievement is now presented as "Laban Lawrence Personal Effort Assessment."

For the record of the movements a trained observer sits inconspicuously at a normally conducted interview busily notating whilst the conversation progresses. Normally twenty to thirty minutes is adequate for this part of the process. He has taken no part in the interview, has paid no attention to the conversation, and is usually referred to just as someone taking notes. Later on the interviewer adds his notes about the candidate's age, technical qualifications, etc., but the observer/assessor does not know these facts and asks not to be told in order to preserve his objectivity in working out the assessment.

The second part—the analysis and assessment—takes several hours and precise conclusions can only be determined by matching the personal effort observed with the job efforts required. This means that a job specification has to be drawn up in terms supplementary to those of the personal effort, so that the result is simply—"this man matches up more completely than any of the others and for these reasons." No attempt is made to assess the level of ability. Instead, assessment is of the direction or channel along which a man is individually exerting his effort. A brilliant man might not match up to the job of general manager simply because he cannot help exerting him-

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WORK MEASUREMENT

By Adam Abruzzi

—a critical review by Harold O. Davidson, Asst. Prof., Dept. of Industrial Engineering, The Ohio State University.

Things have been happening in the field of time study since Ralph Presgrave took a long, unhappy look at it in 1944 ("Dynamics of Time Study"). The latest event of note is Dr. Abruzzi's WORK MEASUREMENT. We would classify it as essential reading for every student, consultant, supervisor, or practitioner of time study.

In our opinion Abruzzi's work comprises several significant contributions. It offers a reasoned perspective of his subject, recognizing the realities of the environment in which time study (for rate setting) is applied as well as the technical problems of establishing standards. In his approach to the technical problems Abruzzi, like Gomberg, appears to have been primarily influenced by the thinking of modern experimentalists. But whereas Gomberg, in his "Trade Union Analysis of Time Study," devoted his efforts primarily to an evaluation of contemporary methodology, Abruzzi proceeds further to the problem of finding bases for a better methodology.

The book is notable also in that it is the first in the field of time study which extensively utilizes the methods of statistical inference. Because statistical methods are relatively new in the field of time study, however, many readers will not be thoroughly familiar with the techniques employed by the author. For this reason we think that he might have devoted more attention to: explanation of the basic concepts of the technique, analysis of the assumptions required and of their effects on test results, and more precise statements of the hypotheses under test. He should have been particularly careful to indicate departures from the methods of statistical inference in view of their prominence in his general approach to the problem.

Because there are such departures in the author's methodology his conclusions should perhaps not be considered as strictly statistical inferences from the experimental data. This is especially so in his studies of local stability, where he decides to infer "stability" even though several points are beyond 3-sigma limits on the control charts for sample means (or ranges). Even with 100 samples (all of the author's studies comprised fewer than 100) two points out of control reject the hypothesis of homogeneity at about the .5% level of significance. Since the author has generally been satisfied with a 5% level it would appear that he could not avoid the conclusion of non-homogeneity. Hence, Abruzzi's definition of "stability," though perhaps useful in explaining his data, does not appear to be statistically rigorous. The decision to allow two points out of control appears to have been a matter of what seemed reasonable to the author rather than the consequence of applying pre-determined objective criteria. It so happens that if two points are "allowed" out of control most of the data obtained by the author could be considered "stable" according to this definition. Strict adherence to the scientific method however, does not permit one to revise or re-define criteria in order that his data may support the conclusions which he attempts to draw. In view of the evidence presented in the book (which accords with what we have found elsewhere) it appears more logically direct and sensible to say that human beings do not perform like statistically stable systems, even though at times the deviations may be remarkably slight.

This may seem a severe criticism—and, in the following sense, it is. Statistics is a the same time a useful tool in research, and a language of logic of uncertain inference. Its utility as a scientific language lies in its capabilities for precise statements, which are due to the fact that its terms have precise definitions. By his departure from the precise meaning of "statsitical stability" the author destroys the precision of the language and assumes a risk of misleading the reader.

On the other hand, the decision to depart from a strictly rigorous analysis is not only permissible but often desirable when statistics is used as a tool course, that this is clearly indicated in in exploratory research (provided, of published results). We do not differ with the author on this account. It is important, however, to note those places where precision has been sacrificed and to be reasonably certain that the sacrifice is not crucial to one's conclusions or subsequent analyses. We consider a "crucial sacrifice" to be one which makes it impossible to choose rationally among several alternative hypotheses or explanations. It appears to us that this situation may exist in the three chapters dealing with the multi-variate tests of independence among "operation elements." The author's identification of these tests is not quite precise, since, strictly speaking, the tests were applied to *observations* of operation elements. Either of two factors could make this a crucial difference.

In the first place, a statistically significant indication of non-independence does not of itself show whether correlations exist among the operation elements themselves, or whether it is introduced into the data by the process of observation. It is not difficult to suggest a plausible manner by which the latter result could occur. We note first that the data were collected by continuous timing with a decimal minute watch, and recorded to the nearest hundredth minute. We note also, from an illustrative sample of the research data, that elements of extremely short duration were observed such that recorded times were either .01 or .02 minutes in some cases. In an observation of this magniture the rounding for such an element is "rounded" down error may be of the same order as the standard deviation of the true time. Furthermore, when the observed time for such an element is "rounded" down to .01, the rounded-off portion will likely appear as an increment in the preceding or succeeding observation—and vice versa. This would tend to produce negative correlations, i.e., a lack of independence in the data. Of course, by combining elements into groups the rounding error in the observation becomes small relative to the variance in the actual time and so the effect might be obscurred. In other words, it is possible to conceive in the observational method a mechanism which would account for the properties which the author attributes to the element times themselves. This does not say that his conclusions are false, but merely that his analysis omits consid-

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The Present and Future of Industrial Engineering

By Dr. Lillian M. Gilbreth

Member of AIIE

—a talk given at a meeting of the AIIE, Oakland, Cal., June 5, 1952.

It is a very great pleasure, indeed, to be here with you tonight. I think the introduction was as fine a demonstration of Industrial Management as I've ever heard.

I'm very glad indeed to talk to you about the present and future of Industrial Engineering and I'm especially glad to talk to you as a member of the A.I.I.E. I have none of the inhibitions of the chairman or of the membership chairman, in telling you a little about the history of the society because it is really a very important part of the presents of this whole movement. I am very pleased to be speaking to a group in which I claim membership.

There, of course, has always been the Industrial Engineering factor in the whole management movement. And going back over the lives of the pioneers, as well as reading the pioneers' writings, these go to show how very important that was. The rise of the whole management movement came right out of the industries in our country. It wasn't something that was developed by the easy-chair group, or "retired" group, or any other of that sort who were remote from the industrial problems. These were men who were working out in industry every day and the whole attempt was to state and bring together the problems which they all faced and then to try to find, through cooperative consideration of these problems and uses of all resources, the ways in which they might get the answers.

The label "Industrial Engineer" I suppose came out during the first World War when our men and women who were working in industry felt that they would like to offer to the country and government such experience and facilities as they had. And in Chicago, under the impetus of that mid-western group, they gathered together and organized themselves into the Society of Industrial Engineers to present their services, not only as individuals and as organizations, or groups, but as a country-wide group of people who wanted to be called upon to be useful. That Society, as you all know, merged later on with the Taylor Society to become the Society for the Advancement of Management which has done and which is doing a very fine job in the management field.

But because the Society for the Advancement of Management also contains many members who are not engineers (and this is right, and we hope it will always continue to admit people who come from a variety of backgrounds and experience) it has become increasingly important—in fact, I think imperative—that there be a Society like this one that concerns itself primarily with the Industrial Engineering problems and where we can be perfectly sure we have a place, a magazine, and an organization where the problems which concern us so deeply can have 100% of the time, energy, and attention which we want to give to them.

I am only going to be able to take up a few of those problems tonight. They are problems of course, which concern many people besides those who are in the industrial engineering field. But they are all problems where we have a very great deal at stake and where we really must devote our attention, not only so that we as individuals and as a group can make our contributions, but so that we may take an appropriate part with organizations extending all over the world.

At the present time, as you all know, we have in this country a National Management Council and on that Council are representatives of all of the large management groups of this country. As the wealthiest, and those most able to give financial support, the American Management Association and the American Society of Mechanical Engineers have given a splendid proportion of that support that is given. But we also have in that Society the Cost Accounting group, the Office Management group, the group in Public Administration, and many others. I am sure the only reason why the A.I.I.E. has as yet not taken out membership in this National Management Council is because we are a very new group, and a group that I have a very great respect for because we are setting ourselves up on a very small money budget but on a very large budget of time and energy and the membership are contributing in that way more, really, than any amount of money could mean.

I want also to say how delighted I am, as I know all the members of the Society are, to have so many women in the meeting tonight. In my opinion it is a very great source of strength to any organization to have the wives of the members present. I happen to be interested in a group in Chicago which puts on our time and motion study clinics every year. That group, started as a very small group and with a miscroscopic budget, really, and yet as the years go on they have put on one of the largest conferences we have in the entire year. They always come out wonderfully well financially as well as any other way. And a real reason is because the wives of the members do every single bit of the work which is done on organizing that conference. They send out the invitations; they come in and register the members; they really do handle all of that type of detailed work which means so much, not only the social side, but on the administrative side. I think it would be a marvelous thing if the A.I.I.E. could develop that same sort of procedure. Many societies have womens' auxiliaries which are more or less useful on the social side, but I know of no other group except the Chicago group where the wives definitely, as a group, have taken over that sort of thing which makes a tremendous contribution. At any rate, I know we are all very happy that you could come. I did not know that you were coming; it seems to me that by far you would prefer that I should give the talk just exactly as I would have given it had you not come, whether or not it proves to be a technical talk before I get through.

How about the present of Industrial Management? I feel some of the emphases are very interesting. For example; this new emphasis we find on the spiritual aspects of management. It was some years ago, perhaps two or three, at a meeting of the Engineering Institute of Canada held up in Montreal, that we had a number of questions sent in. One question asked "What have become of the spiritual values in our industry? Has management any feeling for or apreciation for the non-material things and, if so, what evidences have we?"

The response to that was extraordinary, I thought. This was a panel meeting. Very few of the members of the panel said more than "That is a very stimulating and interesting question, but at the moment I just don't know exactly how to speak to it." After the meeting was over, the secretary of the Engineering Institute and the editor of the magazine had any number of letters from people who said "We heard about this question. We'd like to have you explore it. We'd like more material on the programs." Well, there hasn't been much more material; and I put to you what all of us in this field are putting to ourselves and to each other, "Why".

In the first place I feel that as a group we are rather inarticulate in that field; we have rather left to the people in the churches, and the preachers, and the laymen who are active in that field, and to people who are in perhaps related activities, the talking about these things. We think and we may feel very deeply about these matters but we do not do a great deal of talking. We explored this very recently in a management meeting held every fall up in the Poconos where the management section of the A.S.M.E. puts on an executives' meeting. We wanted a speaker in this area. We thought of one we know could do the job; we knew of another who perhaps might do the job; and there our list stopped. It would be a very interesting thing for you to explore to see if there is an interest in this field, where would you find your speakers, and just exactly how would you bring this thing before your membership.

I feel very strongly that this is an international question in a way. Europe, as they look upon our E.C.A. and M.S.A. missions as they go overseas, feel that we are sending them the American know-how, that we are sending them money, that we

are sending them machines, materials, and methods, but I think sometimes they feel that is all that we are sending them; that this is all that American management stands for, that this is primarily the work of the Industrial Engineer.

And yet, you and I know that the non-material things—the human relations; the human element; yes, the spiritual values, the moral values and those things—are so much a part of the set-up that we wouldn't think, if we were trying to list what America nmanagement covered and what we try to do in our work, of leaving all of those things out of the picture; not because we under-value their importance, but because we consider them of such paramount importance. We know so well that none of the things we tried to do in the other fields would work without that background, but we do take them for granted. That I know, not only from the return of many of our men who have been a part of those missions teams, but from the many teams who are coming into this country.

I always feel as I go around the country what you'd like to have me do is to report the things I have seen at various places. And I can report a little in this respect. I was down in North Carolina in one of the big textile industry towns and I found that on the personnel staff was a man they called an Industrial Chaplain. I was very eager to know just what an Industrial Chaplain did and the kind of a person he was. I didn't know whether the title was a fortunate one—it frightened me a little bit, for I thought back to the early work in the welfare field that sort of got started off on the wrong foot. And some perfectly fine people like John Patterson and others out of the industrial field put in welfare work and really had the best intentions in the world, but somehow or other it got into the public print as a sort of publicity stunt to the point that everyone was very much distressed and felt that welfare really didn't have the good of the worker at heart, but it was a new and none-too-subtle way of putting before the public how philanthropic and benevolent and fine management was to give all these facilities to the workers. And the result of all this was that the workers spoke up vehemently to say that after all they didn't want any of these things; that there was just one little thing that they did want and that was to put the equivalent amount of money in the pay envelope.

Well, you can't exactly put into a pay envelope the sort of things that were at the back of these plans for welfare. But I had that same sort of feeling when I heard this term Industrial Chaplain. What does it mean? Well, I found out that the Industrial Chaplain was just one more personnel person, he was just an ordinary member of the personnel staff but he was a man who had had a Chaplain's background. He had been in a rather small community church which was very non-sectarian. He had seemed to have such a way with people, especially people with trouble, that the industry thought they would add him to the staff to see what would work out. Now, he was not a person who would push himself into situations where he was not very welcome, but he was somebody who, if it was known in the plant that a family or an individual was going through some trying period, could make the contact to see if anything could be done. And if the people were in need of what a church could give, whatever their church might be, who perhaps hadn't been in too close touch with it, he could make that sort of contact for them. Or, if they simply wanted to talk to somebody who had the background and training he had, who had some idea of spiritual values of the serenity that comes from the development of the spiritual life, he could help in that respect.

And then I met him. He was such a cheerful, quiet unassuming person that he made a great hit with me. But more than that, instead of keeping himself in the personnel department—which some very fine personnel people do (although how they expect to handle human relationsp roblems by keeping themselves in their personnel department and not getting out where the people on the job are I never have known)—this man spent all of his time out on the job. Of course, it didn't hurt him in my eyes that he had a great interest in the work simplification, and that he wanted to know ho whe could make the application of it to his own job and therefore accomplish more with his time and energy in the day. But except for his title—and I am still wondering if it was the wisest title—it seemed to me that having someone in the organization, inside a department well known and accepted like the personnel division, who could offer just that sort of thing, was very interesting. . . .

I bring to you as a question: Do you think there is anything in this type of approach which industry seems to be making and whether it has any place at all in the thinking of the future?

The next point I want to make is very closely related to the first one, and that is the tie-in with standards, with codes, with policies, and with beliefs. Now all through the country I found that as the war was over and as people again were going back to the jobs that they were trained for—in the war everyone from top management down to foreman had more or less been changed, promoted or moved onto jobs for which he probably had very little training and was thus struggling along—we tried to say "Where are we and how do we get back to where we ought to be?" And the first thing we found out was that we had to make a re-survey of policy. I think the fact that Industrial Engineering is realizing more and more how dependent we are upon policy is a very significant thing.

If an organization has policies, and is proud that it has policies, and if they are simple and in writing and up to date, and at the disposal of anyone, we in Industrial Engineering have something upon which we can build. So does the whole of industry for that matter. Now it is all very well for an organization to say "Oh everybody knows our policies, we don't have to put them in writing." Well, if everybody knows them what harm can it do if they are reduced to writing; why shouldn't they be in writing? It is very difficult to argue with people who bring this sort of thing up. They seem to feel such a sense of assurance that their policies are perfect and that everybody knows them. If you suggest these policies be put in writing they act as if you were questioning what was said. If policies aren't available to everybody there's something the matter. If they are not simple and clear and up to date—if these people say, "Oh we have them but we haven't looked them over recently. Do you really think there's any need to do so?"—all of such statements can be very honest but can be used in very dishonest ways to conceal the fact that the written policies (the "old" policies) are really only paperwork and are only "front" and all this indicates that really underneath there is not an agreement with the policies by which the organization actually operates.

Now I am sure that every teacher in this group in the management field and many of you who are in personnel relations—in fact, all of you who deal in human relations—have faced the same dilemma that I have: we teach them in college that there are ethical standards, and there are codes and there are fine policies; and then these students come back after they have been out in industry for awhile and they ask, "Didn't you know otherwise or did you try to make us believe that this is the way industry works? It just isn't like you said. The standards are not the same." That's a bitter thing, and all we can do is to say, "Well, evidently you struck the wrong companies. Maybe you've met the wrong men in those companies." We point with pride to the fact that top management in this country, generation after generation, is becoming more and more human-relations conscious, and more and more ethically minded. And while many of us look back with great sorrow to a group who led American industry in a way that could not always be defended, now more and more we are having the right kinds of executives who make the right types of decisions.

Also, of course, we point with pride to the fact that we may have had something to do with this sort of thing; that as we have gone into industry offering our services as consultants or as members of the organizations themselves, we have increasingly stressed the fact that we really must have the sorts of policies upon which we can depend and upon which we will build. Because back of policies are beliefs; and we have a perfect right to ask for and challenge the belief of any group for whom or with whom we are going to work.

Policies do interpret themselves into standards and so you must have standards which are worth something and which you can point to any say, "These are the ways in which we work." I think it is very fine that as we come to the newer groups that are developing—the records and procedures people and the groups that are rapidly professionalizing themselves (like secretaries) or those groups who are developing their professions and who are broadening their scope (like the Office Management group, and the Cost Accounting group, and many many others)—that they do have this appreciation that standards rest on policy, that policies rest on beliefs, and that this whole area is of tremendous importance.

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ENGINEERING IN THE FABRICATION INDUSTRIES

By L. M. K. Boelter

Dean, College of Engineering, University of California, Los Angeles, Cal.

—luncheon session paper given at the Fourth Annual Industrial Engineering Institute, University of California, sponsored by the San Francisco-Oakland Chapter of AIIE, February, 1952.

This discussion shall be confined to the processing of solids (metals, wood, plastics, etc.) and the assembly of components into commodity units or articles which are ready for the consumer.

The problem which faces the engineer may be presented as the following procedure and schedule.

a. Recognition of the need.
b. Evaluation of the objective.
c. Conception of solutions required to fulfill that need.
d. Analysis of all means available to attain that end.
e. Design and/or develop a commodity unit to attain that end.
f. Complete an economic and sociological analysis of the commodity unit and study the implication of the results.
g. Design the production (or construction, or fabrication) procedures and equipment and then possibly redesign the commodity unit itself.
h. Study the actual commodity unit (or product) in the consumer environment and again possibly redesign the commodity unit.

All of the entries in this schedule are rarely the responsibility (or fall under the authority) of a particular professional engineer, but all of the data must be available to him in order that a satisfactory solution will be accomplished.

A criterion required as one step in the establishment of the most satisfactory solution of the problem may be stated as

$$\frac{\partial P}{\partial q_i} = 0$$

where q refers to cost, time, materials, and manpower.

The application of this criterion is the core of professional engineering. Maximizing the elements defined by the procedure (P) with respect to each of these variables (often considered to be independent variables), utilizing the techniques of calculus of variations when possible, and adapting the solution required by the temporal, geographical and cultural environment is implicit in this differential quotient. Or again, the above schedule (P) must be accomplished at the minimum of cost in the minimum time with the minimum effective utilization of men. Minimizing the cost of design and evaluation, production and distribution, sales and service within time limits set (and with adequate restrictions upon effective and proper use of materials and men) requires the utilization of analytical and experimental skills and techniques at the highest level. These skills and techniques include the latest and/or appropriate technical information, technical skills (for instance, network analysis), engineering arts, and the techniques in the trades and of the manual skills. The application of this mass of information to the establishment of a satisfactory designs and product, minimizing with respect to cost, time, materials, and manpower, is implicit in the practice of professional engineering.

In the following discussion only a few segments of the above schedule will be presented.

Flow

The operation of a fully automatic production line requires the temporal and spatial conjunction of events beginning with the materials and ending with a finished product. The temporal sequences can be arranged through the use of automatic computing devices. In a semi-automatic line, the impact of the operator at preselected intervals and locations is required. Parenthetically, in the analysis of a production system, a servo-mechanism can be substituted for man and endowed with those characteristics required at the particular place. Returning to the production line, the usual plant layout will provide the spatial relations but the concept of flow must be introduced to insure the proper space-time consideration. Exact methods of analyzing this flow system have not yet been devised but, for instance, in linear flow, a concept of frequency (units of commodity passing in unit time), volume rate (projected area perpendicular to direction of flow times flow rate, the latter in linear measure per unit time), volume effectiveness (ratio of actual volume of the commodity unit to volume swept per commodity unit), power required per commodity unit and ratio of ideal power to actual power. These variables are point-functions changing from point to point in the system and often exhibit the properties of a discontinuity. Integration and differentiation of these variables yield further data necessary for design and operation.

The satisfactory design will accomplish the given sequence of tasks (assembly or fabrication or other) in the minimum space at the maximum or proper rate compatible with the physical requirements of the machine and the commodity units, and at the minimum cost (fixed-plus operating costs), and also meeting the desired specifications of quality.

The projected areas of the flow paths, including their structural boundaries, on both the horizontal and vertical planes yield further information relative to building layout.

Manpower

So far, the discussion has implied an automatic line, but this goal has not yet been achieved in many instances and indeed may prove unnecessary in certain cases.

But where man's acts are impacted upon the line they may be simulated in the analytical treatment by servo-mechanisms as noted earlier, and the design must include those elements which make effective manual endeavor possible. Adequate lighting (work speed as well as accuracy depend on the illumination an dcontrast), the proper sound level (noise is enervating), proper ventilation (correct temperature, humidity, air velocity, air purity, no drafts, correct ratio of radiant to convection fraction of thermal energy to the man), absence of vibration (different frequencies and amplitudes affect the different parts of the human body differently), and preventive safety features must be incorporated into the design.

To this end, all that is known about man's response to the environment created by the engineer must be brought to bear. Many data are not yet available—for instance, the effect of air temperature and humidity on the rate and accuracy of the performance of certain tasks. Parenthetically, a research project is under way in the University of California in which the effect of abnormal temperatures from 125° F to 300° F are being studied.

From another point of view, what tasks can man perform with no deteriorating effects on his health and well-being? Again, a small beginning is being made at the University of California. Elementary tasks have been analyzed, segregated into unit-operations, and the minimum number of skeletal-kinemetic links necessary to perform these tasks has been established. At the moment, the work is being directed toward the design of prosthetic devices but will soon be broadened to include other objectives.

The time-space relations at those production stations at which man contributes deserve and have received special attention. The accomplishment of these tasks minimizing fatigue, monotony, enervation, waste motion, and danger by and to the worker is the goal to be achieved. Energy-motion-time relationships have been established for many specific tasks. Application of these data is mandatory in good engineering practice, but greater knowledge of the physiological and psychological response of men to engineering systems is needed for rational design.

The plant designer should also carefully consider its location. Many geographical, legal, resource availability, and disposal problems must be answered. But restricting this segment of the discussion to man, he must be rested and alert when reporting for work. Long enervating drives between home and work are not conducive to the greatest well-being of the employee and of management.

(Continued on Page 22)

Developing Standard Data for Predictive Purposes

By Adam Abruzzi

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—a talk given at the Work Measurement Session of the Fourth Annual Industrial Engineering Institute, University of California, sponsored by the San Francisco-Oakland Chapter of AIIE, February, 1952.

The problem of whether standard data can be developed for predictive purposes is one of the most fundamental in work measurement.[1] The basic approach and procedures of standard data are essentially the same today as when they were developed by Taylor, who first proposed that element or motion times be developed for the purpose of predicting cycle times for operations with similar elements or motions.[2]

In general, it is believed that production standards developed from element standard data are both accurate and consistent with one another. Carroll, in fact, is so impressed by the belief that standard data are consistent, that he makes the sweeping assertion that the standard-data approach has no disadvantages and can be applied almost universally.[3] The claim of consistency is so persuasive that it is supported by Gomberg, who is otherwise quite critical of the standard-data approach.[4]

Another significant advantage claimed for element standard data is its superiority over motion standard data. Mundel, for example, considers this superiority to be established by the results of certain laboratory experiments indicating that the time required to perform one motion is influenced by the preceding and subsequent motions.[5] A number of writers take the opposite view, claiming essentially that accurate results cannot be obtained from element standard data as developed by the usual time-study procedures.[6]

There can be no doubt that if these claims are true, the standard-data approach can solve many estimating problems in work measurement at a minimum cost. There is one critical qualification: **it must first be shown to have the properties claimed.** Putting this in more technical terms, standard data must be shown to give predictions that are both accurate and precise (or valid and reliable). The answer to this fundamental question is long overdue, for recent surveys show that substantially more than 50 per cent of time-study practitioners now develop and use element standard data for predictive purposes.[7]

It is instructive to summarize the available critical views and experimental results on the subject of element standard data. As early as 1916, Hoxie commented that the use of standard data introduced a further unscientific and possibly unjust factor into work measurement.[8] He also made the prediction that its only potentially useful application would be on machine-controlled operations.

In recent years this subject has received a great deal of critical consideration, particularly by industrial psychologists, such as Ryan, and Ghiselli and Brown.[9] Essentially, their position is that: (1) element standard data can be developed only if it can be shown that the times of differential elements are independent; (2) element times seem to be interdependnt rather than independent.

A small amount of experimental evidence has been reported on these questions, primarily by Barnes and Mundel.[10] They found that the time required to perform a movement is influenced by the preceding and subsequent movements, which suggest that motions, at least, are interdependent.

These views and results do have a certain amount of exploratory value: they show that there is some doubt that motion times are not independent and hence that standard data predictions made from them may not be very useful. However, the extremely limited number of experimental studies reported were made under laboratory conditions on extremely simple tasks performed by small groups of highly motivated test subjects. Much more intensive studies were clearly needed on representative industrial workers performing representative industrial tasks under representative industrial conditions. This is exactly what was done in the research project about to be described. Moreover, the problems involved in evaluating the standard-data approach are much more complex and subtle than the available critical and experimental evidence suggests; it was necessary, for example, to employ a number of so-called statistical procedures to analyze the test data.

The first set of studies was made on element data obtained from representative time studies of man-controlled operations in representative plants of the garment industry. These studies were intended to determine whether the element times in individual operations were independent of one another. Thus, the relationships, if any, among all the elements involved were studied by making a single over-all test, called the Wilks' multivariate test of independence.

The application of this test is quite involved and will therefore not be discussed here; the pertinent details and the data obtained can be found in "**Work Measurement:** New Principles and procedures."[11] For present purposes, it is sufficient to summarize the results obtained.

The first general finding was that as originally defined, the elements in the operations considered were generally not independent. Since this turns out to be a crucial point, it should be understood that the element definitions were developed by plant time-study analysts with some assistance from union time-study analysts. These definitions were based on the criteria usually used in the time-study field, e. g., sound and motion "breaks," and so forth.

The test results further showed that not only were the elements in these operations not independent, they were actually tied together by a complicated network of relationships. It should be stressed that: (1) a relatively large number of test studies were made; (2) the data were obtained in the factory rather than in the laboratory; (3) the findings were based on established statistical test procedures.

The test results also produced two more findings of fundamental interest. They showed that the nature and the degree of the relationships among the elements depend on the number and the magnitude of the elements involved. They showed further that the nature and the degree of the relationships vary with different operators and even with the same operator. A large amount of supplementary empirical evidence was also obtained, showing that almost all workers organize their work patterns in terms of the operation as a whole rather than in terms of individual elements.

On the basis of these findings, another set of studies was made to determine whether it is possible to redefine operation elements so that they will be independent. The procedure adopted was to combine two or more elements into groups, which were then considered as the primary operation subdivisions instead of the original elements. These groups were developed on the basis of the statistical and empirical evidence previously obtained. Thus, if elements 1-3 in operation A had a high degree of correlation and they seemed to be performed in terms of an integrated series of motions, the times for these elements were pooled to obtain the times for element group 1, etc.

The primary conclusions obtained in this set of studies were that: (1) in most cases independence (i. e., among element groups) will be achieved after the first application of the grouping process; (2) independence will not necessarily be achieved even after two applications of the grouping process; (3) the amount of grouping required to achieve independence varies with the operator; (4) the number of element groups required to achieve independence varies from plant to plant. (In one plant, independence was usually achieved with from five to seven element groups, while in another, the grouping process had to be continued until only three to five element groups remained); (5) independence is much more likely to be achieved when the average time of the smallest element group is at least five hundredths of a minute and the average time of the median element group is at least ten hundredths.

It is quite important to emphasize that independence is not

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PRACTICE VS. THEORY IN SAMPLING INSPECTION

By Henry P. Goode
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—a paper given at the Quality Control Session of the Fourth Annual Industrial Engineering Institute, University of California, sponsored by the San Francisco-Oakland Chapter of AIIE, February, 1952.

When I was asked to give a talk on quality control as a part of this institute, I suggested a number of possible titles in a note to the general chairman. Among them were "Some Unsolved Problems in Sampling Inspection," "Choosing the Correct Sampling Plan," and the title you find on your printed program. I must confess they all were for the same speech. What I intend to talk about is (a), some of the problems waced by an industrial concern or any other agency that purchases material, parts, or completed product in selecting the best sampling inspection plan for each product and supplier, (b), how, in theory, a choice should be made, and (c), how and why present practice differs from theory.

In sampling inspection, the purchaser or receiver groups submitted products into inspection lots. Then each lot is sampled by drawing at random a number of items. These items are inspected and on the basis of what is found, the entire lot is either accepted or rejected.

Sampling inspection is very widely used for the acceptance inspection of purchased goods and material. In addition, the use of sampling inspection for in-plant quality control is increasing.

Until recent years, sampling inspection was crude and unscientific. One simple sampling plan was used for virtually all applications. A sample whose size was 10 per cent of the number of items in the lot was drawn. The sample items were inspected and if no defective items were found, the lot was accepted. Otherwise, it was rejected. This practice had one virtue—there were no problems of selecting a sampling plan. However, it was seriously inadequate for modern manufacturing methods and products. First of all, it gave almost no protection against the acceptance of bad lots in many of its applications. Second, at considerable inspection waste, it gave too much protection in many more applications. This plan was really satisfactory for only a limited range of acceptance conditions.

Now, a number of sets of scientifically designed sampling plans are available for general use. Each set contains a number of different plans so that a satisfactory one may be selected for the particular technical and cost conditions surrounding any possible application. The first set made available was the Dodge-Romig plans developed at the Bell Telephone Laboratories for use at the Western Electric Company. These are now used in many different firms and industries. Additional sets have been developed under the auspices of different branches of the Armed Services. Military Standard 105-A, the set currently used by all branches of the Armed Services, and the plans established in "Sampling Inspection" which were developed by the Statistical Research Group at Columbia University are examples. These military plans are also widely used by industrial concerns.

The plans in each of these and other available sets are soundly designed. The ability of each to discriminate between lots of different quality has been carefully described. A wide variety of plans to cover a full range of conditions has been made available. In Military Standard 105-A, for example, there are 430 different plans. These plans are for attribute inspections (inspection in which an item is simply classified as defective or non-defective) alone. If a parallel set of plans for variables inspection (inspection in which the property of the item is measured and its quality considered in terms of this measurement) is to be used also, several hundred more plans are added to the collection from which a choice must be made for each application.

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The problem now faced by the user, after he has decided on the set or sets of plans he is to use, is to select for each product and supplier the particular plan to apply.

From a cost standpoint, making the right choice is important to both the receiver and the supplier. A poor choice must have one or more of these costly consequences:

(a) The acceptance of a large proportion of the lots that should be rejected.

(b) The rejection of a large proportion of lots that are satisfactory and so should be accepted.

(c) Undue sampling inspection costs because unnecessarily large samples are drawn.

In a full defense or war economy, the consequences represent an unnecessary waste of irreplaceable labor and materials.

When selections are poorly made, the potential value of these carefully designed scientific plans is largely destroyed. Both good plans and the proper use of them are essential for adequate quality control and reasonable acceptance inspection costs.

Forms of Sampling Inspection Plans

Sampling inspection plans may differ from one another in one or more of four basic ways: (1) they may differ in the sharpness with which they discriminate between acceptable and unacceptable lots, (2) they may differ in quality levels at which lots are considered acceptable, (3) they may differ in type of sampling, and (4) they may differ in the type of item inspection required. For each incoming product and supplier, a choice must be made from among the available possibilities for each of these kinds of differences.

In considering these differences, it is helpful to think of each plan in terms of its operating characteristics, a property which may be conveniently described by an OC Curve or operating characteristic curve. For example, if a plant is to draw from each lot a single sample of 75 items, to inspect them on an attribute basis, and then to accept each lot for which no more than 3 defectives are found in the sample, its operating characteristics are as shown by the OC Curve in Figure 1. This curve

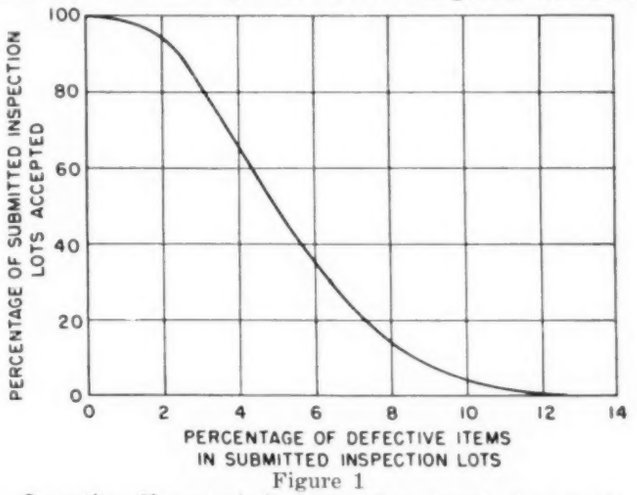

Figure 1
Operating Characteristic Curve when Sample Size is 75 and Acceptance Number is 3.

shows that when the percentage of defective items in submitted inspection lots is 2 per cent or less, virtually 100 per cent of the lots will be accepted. If the percentage of defective items in

submitted lots is 12 per cent or more, virtually all the lots will be rejected. Instead of reading from the curve the percentage of submitted lots that will be accepted we may, if we wish, read instead the probability of accepting a lot of any quality. For example, this OC curve shows that if a lot is 5 per cent defective, the probability is about 50-50 that it will be accepted.

The ability of a plan to discriminate sharply between good and bad lots—that is, the steepness of its OC curve—depends mainly on the number of items making up the sample. The larger the sample, the sharper the slope of the OC curve and the better the plan can discriminate between one lot quality and another. Note that it is the absolute size of the sample that counts and not its size in relation to the size of the lot. The effect of sample size is shown in Figure 2, which gives OC curves for five plans, each with a different sample size but all of which are designed to accept virtually all lots with 2 per cent defective or less. The dashed line on this figure represents the ideal OC curve. The perfect discrimination it represents can be achieved only by inspecting all the items in the lot.

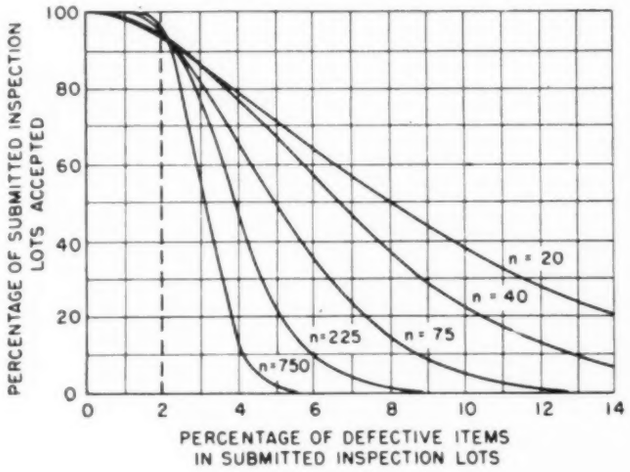

Figure 2

OC Curves Showing Effect of Changes in Sample Size.

The quality level at which lots will be considered good—that is, the position of the OC curve from left to right on the percentage of defective items scale—is determined mainly by the acceptance criterion for the plan. In our example, it is determined by the acceptance number, which is the maximum number of defective items that are allowed in the sample for the lot to be accepted. The effect of changes in acceptance criteria is shown in Figure 3, which gives OC curves for five plans, all with a sample size of 75 but with different acceptance numbers.

Sampling plans differ in two ways in the kind of item inspection required. Until recently, all sets of plans generally available were for attribute inspection. A set has now been made available for variables inspection.

Plans also differ in type of sampling. Some require only one sample for reaching a decision to either accept or reject. Others depend on drawing one additional sample or a number of additional samples from lots of doubtful quality. Multiple sampling plans will be described in more detail in a following section.

Objectives in the Choice of a Plan

The choice of a sampling plan depends on the objectives of acceptance inspection. Insofar as quality is concerned, there are two principal objectives. The first is to obtain some immediate protection against the acceptance of unsatisfactory product. The second is to put pressure on the supplier to improve his quality if the general quality level of submitted product is not satisfactory. This last objective is perhaps more important than the first. Very frequently, sampling inspection can be of little help in screening bad lots from good. A third, and important objective, is to achieve the desired quality objectives in a way that minimizes all the costs that are affected by the choice of an acceptance procedure. These costs include the costs of accepting and using defective items (and particularly the costs of accepting lots with an unacceptable percentage defective). They include the costs—both immediate and eventual—of rejecting lots and returning them to the supplier (particularly if the rejected lots are good), and they also include the costs of acceptance inspection.

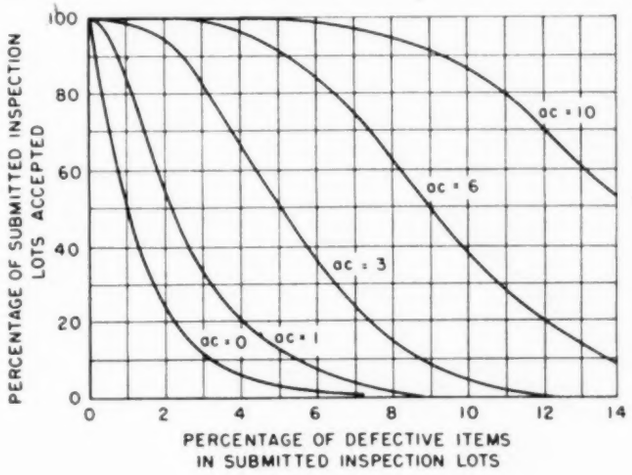

Figure 3

OC Curves Showing Effect of Changes in Acceptance Numbers.

The Choice of a Quality Level that is Acceptable

As has been indicated, a specific plan to use for an application is selected, or should be selected, by making a number of decisions. Perhaps the most important one is to select a lot per cent defective which is acceptable. In effect, this means choosing the general location from left to right for the OC curve.

In theory, the person making this selection should first of all determine the costs of accepting and using each of all possible percentages of defective items. These costs should include both the added expense in further processing the materials or parts in his own plant and the tangible and intangible costs of defective items that leave the plant as a part of his firm's product. He should then attempt to determine the costs to the supplier of producing different levels of quality. Finally, he should determine how bodly his firm (or branch of the Armed Services) needs the submitted product and the costs of delay if all or part of it is returned. With this information available, he should then choose from among all available possibilities a position for the curve that minimizes all these costs.

It should be apparent that making an optimum choice may be quite a problem. First of all, it is usually difficult to determine and evaluate the costs connected with accepting and using defective items. Many of them are irreducible to money terms, particularly if the receiver is a branch of the Armed Services. How can one determine the costs (in terms of dollars) of accepting a defective gas mask, for example? Also, it is equally difficult to find the relation between cost and quality for the supplier so as to determine how much pressure, if any, to exert for quality improvement. Since eventually the costs of quality improvement must be passed on to the receiver, he must be sure they will be justified. The costs of returning lots when the material is badly needed may be determined reasonably well if the receiver is an industrial concern, but if the receiver is a branch of the Armed Services or a firm producing for them, to do this is difficult in war-time.

Because of the difficulties outlined above, and because of the difficulties of summing up the costs if they were available and making the best decision in a routine way, a simple and practical solution has developed. It is a selection procedure which is used with fair results quite generally by both industry and the Armed Services. Essentially, the procedure is to estimate what the quality of submitted lots will be and if the quality expected is satisfactory, to choose a plan that will accept virtually all lots of such quality. No formal consideration is given the economic factors listed above. An estimate of what incoming quality will be is something that, after some experience, can be determined reasonably well. Hence it supplies a basis

for a choice that can be established even though it is not a basis that is fully adequate.

Until recently, the per cent defective to expect for an incoming product was simply determined by an undocumented estimate by some person who had experience with the product and the supplier. A rapidly growing practice in the past few years, however, has been to compile and summarize in written form quality histories for all products and vendors. These histories are mostly a record of past acceptance sampling inspection results. In the absence of any new knowledge to the contrary, it is assumed that future lots that may be submitted will have the same percentage of defective items as those submitted in the recent past.

To aid in selection under this procedure, most sets of plans used in this country have each plan classified or described by a point on its OC curve, called the "acceptable quality level" or AQL. The AQL of a plan, as the term is commonly used, is the percentage defective in submitted lots at which 95 per cent of the submitted lots will be accepted. The AQL of the plan whose OC curve is shown in Figure 1 is 2 per cent. The selection of an AQL thus fixes the position of the OC curve which in turn determines the quality level at which lots will be considered acceptable.

Generally, a plan with an AQL equal (or as close as possible) to the estimate of incoming quality is selected. However, if this level of quality will not be satisfactory in the receiver's use of the product, an AQL at a somewhat lower percentage will be selected. This will result in a plan that will reject a larger proportion of unsatisfactory lots than would otherwise be the case. What is more important, the increased rejections will presumably induce the supplier to improve his quality and send better lots in future shipments. (An interesting problem in this connection is to determine how much rejections must be increased to induce the supplier to make the right amount of improvement.) If the estimate of incoming quality is better than the level that could be satisfactorily used, an AQL somewhat higher could be selected. While this might be in the best interests of both parties, such a practice is seldom found.

Most users of sampling plans who make a selection in the way just described have, as a part of the procedure, a more or less formal routine for making a change in the AQL if incoming quality turns out to be worse than the estimate or if it deteriorates at some time in the future.

A few users have been encountered who make one AQL value, or perhaps two, do for all products and suppliers. Apparently, the reason for this is that information for making a logical choice from among the many values that are available cannot be obtained. One user who is a large purchaser of goods and materials uses an AQL of 1 per cent for approximately 99 per cent of his applications and an AQL of 5 per cent for the remaining 1 per cent. (Round figures like 1 per cent, 5 per cent, and 10 per cent seem to have wide use when bases for selecting a logical figure are not available.)

The selection of a plan in terms of an AQL is advantageous when it is important to accept as much product as possible and when a long-run quality viewpoint can be taken. However, from the standpoint of immediate quality protection, a selection in terms of the other end of the OC curve might be better—the percent defective in incoming lots beyond which virtually no lots will be accepted. For this reason, most sets of plans have also been cataloged by a point on the low end of the cruve—the "lot tolerance per cent defective" or LTPD. The LTPD, as ordinarily defined, is the per cent defective in incoming lots at which 10 per cent of the lots will be accepted. For the plan whose characteristics are pictured in Figure 1, the LTPD is 8.8 per cent.

However, few places can be found in which a selection is made in this way. A selection made in this way must be made mainly in terms of the per cent defective that can be used without too much difficulty, a figure that is hard to determine.

A European method is to classify and select plans in terms of the mid-point of the curve—the point at which the probability of acceptance is 50-50. For the plan in Figure 1, this is at 5 per cent defective. The argument for making a selection in this way is that a selection is found that compromises the conflicting desires of the supplier and the receiver. The supplier wants the position of the curve to be as far to the right as possible; the receiver wants it as far to the left as possible. A value is chosen as a compromise for these views and a plan chosen whose mid-point goes through this value.

The Choice of OC Curve Slope

The next decision that must be made is that of deciding for the application how sharply the plan must discriminate between good and bad lots. In effect, this means choosing the slope for the OC curve.

As previously pointed out, the slope of the curve depends mainly on the size of the sample. The larger the sample, the better the plan will discriminate between good and bad lots. Note in Figure 2 (which gives OC curves for five plans, all with an AQL of about 2.2 per cent), that if the sample size is 20 about one-half the submitted lots with 8 per cent defective will be accepted, while if the sample size is 225, virtually none will be, for example. The added discrimination of the latter plan, however, is achieved at the cost of considerable increase in sample size.

The problem, then, is to determine what slope (and thus what sample size) will result in a minimum total cost, considering both the costs of drawing and inspecting sample items and the costs of making wrong decisions. Sampling inspection costs for different sample sizes can be determined fairly well. However, the costs of wrong decisions are difficult to estimate. They include the costs of accepting lots with more than an allowable per cent defective and the eventual costs of rejecting lots that should have been accepted. Also, a part of this problem is to determine the number of lots that should be returned to furnish the right incentive for quality improvement if at any time the quality supplied falls below the acceptable level.

In actual practice, much of the information required for making the best choice of slope is difficult or impossible to obtain. For this reason, a more or less arbitrary choice is made. Most sets of sampling plans are cataloged according to "inspection levels." The choice of level determines the relative amount of inspection that will be required. The middle level is designated as the level most suitable for "normal" use, with the choice of a lower level or a higher level being available for applications for which the cost of inspecting an item is unusually high, for which the acceptance of bad lots will cause considerable difficulty, or for which some other unusual condition makes a different level advisable. It may be observed, however, that the normal level is used for practically all applications.

Actually, the choice of a level (or the consistent use of the normal level) determines a range of sample sizes. Within the level, the specific sample size to use is determined by the size of the lot. For example, with inspection level II in the Military Standard 105-A plans for single sampling, for a lot size of 66 to 110 items, the sample size is 15. For a lot size of 1301 to 3200 items, the sample size is 150.

From the standpoint of protection alone, the sample size for an application should not depend on the size of the lot. The ability of a plan to discriminate between good and bad lots depends on the absolute size of the sample. The relationship between sample size and lot size for this viewpoint—constant protection—is shown by the horizontal line in Figure 4. However, from the standpoint of keeping acceptance inspection costs per unit of submitted product constant, regardless of lot size, the sample size should vary directly with lot size. The relationship for this viewpoint—constant inspection costs per

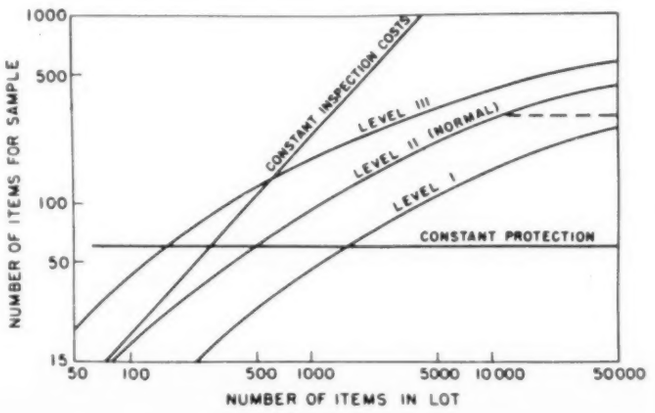

Figure 4

Relation of Sample Size to Lot Size, Single Sampling

unit submitted—is pictured by the diagonal straight line in Figure 4.

In establishing the sample size for each range of lot sizes, the plans designers work out a compromise between these extreme points of view. The compromise allows some increase in sample size for large lot sizes but not a proportional increase. At the same time, it keeps the sample size for small lots large enough to give a reasonable amount of protection. The relationship between lot size and sample size for each of the three inspection levels of the 105-A plans is indicated in a general way by the three curved lines in Figure 4. (Actually, the sample sizes do not vary continuously. One sample size is used for a range of lot sizes.)

It should be apparent that determining a relationship between lot size and sample size that will be best for "normal" use by all branches of industry and the Armed Services is a difficult problem. It is one that seems to warrant further study.

One practice commonly encountered indicates that one aspect of the relationships now prescribed may not be right. This practice is to arbitrarily set an upper limit for a product or a class of products on the size of the sample, regardless of the size of the lot. The effect of this practice is indicated by the dashed line at the curve for Inspection Level II in Figure 4. Arguments for such a limit are (a), that it is difficult to draw very large samples in a random manner, (b), that the inspector becomes fatigued after inspecting several hundred items so that the inspection of additional items is of little help, and (c), that the drawing of very large samples requires the opening of too many containers or in other ways causes unjustified trouble and confusion (particularly when inspection is at the shipping department of the supplier's plant, as is often the case.)

The Choice of Type of Sampling

It is possible to obtain desired operating characteristics by any one of several forms of sampling. In the discussion up to now, single sampling has been described. The other forms are available as alternatives in the sets of sampling plans generally available. They are double sampling and group sequential.

In double sampling, a relative small first sample is drawn. It is inspected and if very few defectives are found, the lot is accepted at once or if very many are found, it is rejected at once. But if an intermediate number is found, a second sample is drawn and inspected. On the basis of what is found in the two samples combined, the lot is either accepted or rejected. The group sequential form of sampling is the extension of the double sampling procedure to the possible drawing of a number of samples.

These forms may be illustrated by the following three plans, all of which give approximately the same OC curve:

Single sampling — Sample size 225
Acceptance number 14
Rejection number 15

Double sampling — First sample size 150
Acceptance number 9
Rejection number 24
Second sample size 300
First and second combined 450
Acceptance number for combined sample 23
Rejection number for combined sample 24

Group sequential —

Sample	Size	Combined	Acceptance Number	Rejection Number
First	50	50	1	6
Second	50	100	3	9
Third	50	150	7	13
Fourth	50	200	10	16
Fifth	50	250	13	19
Sixth	50	300	16	22
Seventh	50	350	19	25
Eighth	50	400	24	25

Multiple sampling plans offer a means of reducing the average amount of acceptance inspection. Very good lots are accepted at once and very bad lots are rejected at once by a relatively small amount of inspection. Additional samples are drawn as needed to make a decision for lots of intermediate quality. For example, with the attribute plans just given the average amount of inspection for each for different incoming qualities, is as shown in Figure 5. If it is feasible to return to the lot and draw additional samples when necessary, multiple sampling plans offer possibilities for real savings.

It appears, however, that single sampling is almost always employed in spite of the savings the other forms offer. One reason commonly given is that quality histories cannot be built up quickly enough if single sampling is not used. Only the first sample in multi-sampling plans can be used if an unbiased estimate of incoming quality is to be obtained. Also, it seems that double and sequential sampling is considered by some to be too difficult to explain and justify. In the double-sampling

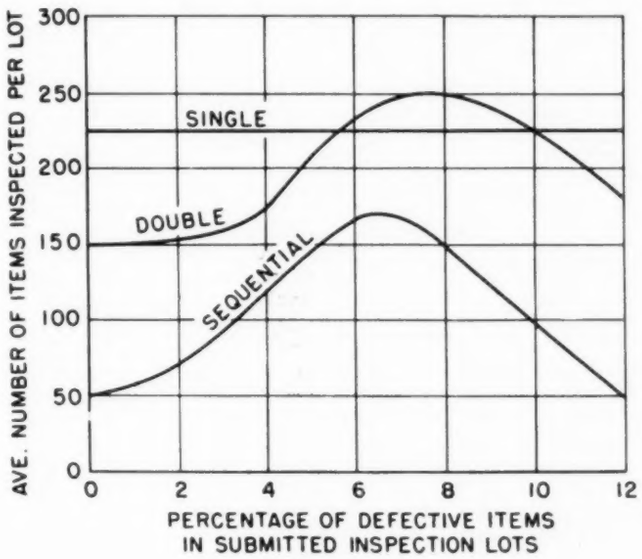

Figure 5

Average Amount of Inspection for Single, Double and Sequential Plans

plan shown in Figure 5, to take an example, for a lot of 20 defectives might be found in the first sample of 150 items. In the second sample of 300 items, it might happen that only 4 defectives are found. The total number in the two combined, 24, is enough to require rejection, however. Since the lot was not rejected after defectives were found in a sample of 150, the supplier may not understand why it must be rejected as a result of finding only 4 defectives in an additional sample of 300. A final argument in the case of procurement offices of the Armed Services is that it is essential to have uniform and known work loads for their inspectors. Schedules for acceptance inspection, which is usually carried out in the vendor's plant just prior to shipment, must be maintained. In multiple sampling, the amount of inspection that will be required in any specific case cannot be predicted.

In a few places, double-sampling plans are used for a few applications. Also, among the operations I have observed, two large industrial concerns are using sequential plans exclusively. Their experience has been, and this is backed up by extensive records, that most submitted lots are either quite good (which is usually the case) or quite bad. A decision is almost always made on the first, or possibly the second, sample. Since this is so, they have realized appreciable savings in inspection costs by the use of this type of plan. No particular problems have been found. Inspection management in both these concerns are quite enthusiastic about sequential sampling and feel that many other concerns could change to it with profit if they would just try.

The Choice of Method for Item Inspection

Until recently, all generally available sets of sampling plans were for attribute inspection. In attribute inspection, an item is checked by a go and not-go gauge or other device, and simply classified as either satisfactory or unsatisfactory. However, in a short while a comprehensive set of plans will be available for variables inspection, inspection in which the item quality is measured and recorded in terms of inches, ounces, volts, or some other unit.

The important advantage of sampling inspection by variables is that fewer items have to be inspected than under an attribute plan with the same operating characteristics. More is known about an item if a specific measurement is available than if it is simply known to be bad or good. For this reason, measurements for sample items give more information about the lot than attribute information.

The effect of this practical advantage is indicated by the following examples of sample sizes:

Sample size for attribute plan	Sample size for variables plan	
	Unknown standard deviation	Known standard deviation
10	7	5
30	16	9
75	35	16
225	70	28
450	100	36
1500	200	45

The above illustrations are for single sampling. The savings are comparable for double sampling.

The disadvantages in using variables plans are that the inspection of an item may be more costly than under attribute inspection and that the computations required for making an acceptance decision are more involved. However, when the drawing of sample items is difficult, when attribute inspection requires about as much time as variables, and when inspection damages or destroys the item, the use of variables plans may be preferable. The set of plans are matched with an available set of attribute plans so that the two sets may be used on a parellel basis for a complete inspection program. A decision as to the set to use for an application can be made simply in terms of the respective acceptance inspection costs after a decision as to operating characteristics has been made.

The Formation of Inspection Lots

A problem related to those just outlined when applying sampling inspection plans is that of forming inspection lots. In theory, a shipment of goods should be subdivided or grouped into lots that are most suitable for acceptance inspection purposes. In forming these lots, product from different machines, different operators, different dates of production, and the like, should be kept separate so as to maximize the opportunity for difference in quality from lot to lot. If this is done, sampling inspection can be most effective in screening good lots from bad. If inspection lots are all alike, some lots will be accepted and some will be rejected, depending on the effect of chance in the drawing of sample items. The lots that are accepted will be no better than the ones that are rejected. At the same time, when forming inspection lots, the lots should be made as large as possible so that larger samples (with the better discrimination they afford) can be used economically.

For the above reasons, the formation of lots should be an important matter in getting desired protection at a minimum cost. In practice, however, little or no attention is given to this step, apparently. If any one rule is followed, it is to make the inspection lot as large as possible regardless of whether product that may differ in quality is combined. An entire day's production or an entireshipment is usually taken as the inspection lot, no subdivision being made . If acceptance inspection is carried out in the supplier's plant, the floor space available for accumulating the product or the inspector's work schedule may be the determining factor in making up a lot.

Summary

The aim of this discussion has been, first, to show that it is just as important that sampling plans be properly selected as it is for them to be correctly designed. Next, the aim was to point out some of the problems in making a rational choice and how in practice plans are ordinarily chosen.

The intent has not been to speak slightingly of current sampling inspection plans and their use. Their wide employment is with good effect in almost all cases. The scientific approach to quality control through sampling inspection plans and the control chart technique, is one of the most important management developments in recent years. The one thing that to some extent remains to be done is to develop better ways of using these new tools so that the benefits of which they are capable will be more fully realised.

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PRESENT AND FUTURE OF INDUSTRIAL ENGINEERING

(Continued from Page 13)

The third question I want to bring before you is this whole question of the relationship of technical adequacy, and of adequacy in the field of human relations. Now it may be true that for many years engineering—and industrial engineering as a part of it, and the whole management group as affiliated—did put a tremendous emphasis upon techniques and upon technical effectiveness. Far be it from me to apologize for technical development of this country. How could we have gained the know-how to use ourselves or to export it if we had not had it? On the other hand, it is very interesting that the pendulum seems to swing back and forth in this whole field of human relations. I think that this present tremendous emphasis on the human element was started right here at a San Francisco meeting (or it may have been on the campus at Berkeley or Stanford) of the American Management Association where Alvin Dodd, in a most splendid, persuasive and fine way—he was one of the finest men we ever had in the management field—did emphasize the fact that without human relations, or without the human element pervading everything, technical adequacy could not get you anywhere.

Well, of course, we have realized that. Especially, I think, we realize that in Industrial Engineering because we work directly with the man on the job. And we know right well that without his cooperation, without his participation, without his motivation and interest in it, we can't possibly get anywhere. But I don't know who deserves the dis-credit (for it certainly is not the credit) of feeling that in some way or other if you diminish your technical effectiveness you would automatically build up your human relations. That seems to me the most illogical, really the most foolish assumption anyone ever thought about. In the first place, as a matter of actual fact, we know that most of our people who are top flight people in research, in science, in the techniques are also top flight personalities. People. Their human relations are wonderful.

Just a day or so before I left New York, we had the first meeting celebrating the Centennial of the Civil Engineers. The Metropolitan section of the Civil Engineers of New York invited all the other groups to come in for a meeting. And for once, the dear old Engineering Building's auditorium just simply overflowed with engineers of all types and kinds,—the student groups, the junior groups, the senior groups, every group you can think of—and the speaker was Vannevar Bush. Well, I think his technical achievements don't need any explanation before any group in this country. Yet he is the most warm hearted, the most human, the most generous thinking sort of person you can possibly think of. We have examples all along the line: the Comptons, Millikens, leaders in every field of engineering and of management who are highly adequate technically and also wonderful in the field of human relations.

I wanted to mention this especially tonight not only because I feel so many of you can do something about this, but because I think it's one of the most important problems which we face. We cannot allow technical adequacy to diminish in this country. It not only has to be maintained, but it has to be developed and it has to go all the way down from pure research to the application on your job and on mine. But at the same time we do have this responsibility of building up the personnel relations and having the feeling of give and take in the human side grow more and more effective.

There's another assumption which also is something we should bring before ourselves and look at and that is that everyone who is labelled as being in the personnel department is, just because of that, a person who is really wonderful in

the field of human relations. Now, he may be or he may not be. There are people in the personnel department who are just as technically minded on the test side or on the interview side or on the questionnaire side or on a dozen other sides as anybody who is working out in quality control or in any other technical developments in our field. What we really are talking about is people who know how to get on first with themselves—for that is tremendously important—and then with other people in every relationship of life. Because when we've got all the way through we may talk about labor relations and industrial relations, but they are human relations all the way along the line. And what we want is people who, in their homes or on their jobs or wherever they may go in the whole world can get close to other human beings with a give and take that will work.

Let me give an example. We send a man overseas to do one of these contact jobs for us in the field of industrial management. He may or he may not know the language of the people. In my opinion, he ought to know the language of the people. This country is full of men and women whose parents came from all these countries who heard these languages as youngsters and many speak them fluently in their homes. Nobody seems to be hunting up these people and saying "Do you also have this, that, or the other technique; do you have this, that or the other human quality **plus** this ability?"

No, they get some kind of a translator. Well, I think translators are wonderful people; I just listen to them with the greatest admiration. But we are having some queer experiences with our translators. A good many of them know the language of the country for whom they are to translate and they know our language, but they don't know the technical language at all. And you'll get a group—let's say from Japan—who will come all the way to New York and they will send somewhere (heaven knows where) and get somebody who speaks Japanese and who also speaks American. He can do that sort of translation and you get him in and you begin to say "Tell this group this, that, or the other thing" and the translator throws up his hands and says, "I never heard any of those words before." And you and I just don't realize that while we are so proud that we speak simply and plainly and we all understand each other, we really have a lot of technical terms in industrial engineering and very often if the Japanese speaks even a little English he will tell the interpreter what we are trying to say and then the interpreter can go on and interpret the "this" "ands" and "buts" and we get on very happily indeed. That sort of situation, it seems to me, must go on in these European contacts and not really be realized by anyone at all.

Another thing I think often happens in our contacts with these overseas groups is the fact that we fail to appreciate what they have done in the past and in the present. I feel very strongly on this. I talked to a number of groups who came from various countries and in almost every case when I have started by saying "Your country did a great deal for management in the early days—you had pioneers in your own field (in the case of France, for example, the work of Fayol and that group of Frenchmen did pioneer work in municipal and other administration far ahead of what we are doing hardly even today.)—you translated our pioneers into your language. And you used their work, in spite of the fact that you had very little material, very few machines, and a terrible dearth of men. You've accomplished marvels in the past. I hope while you are in this country you will know that you are here not only as learners, you are here as teachers and we are eager to know not only what your problems are but how you have solved problems. Because probably in many cases, given what you have had to solve them with, you've done a better job than we have. We have the same problems but we have immeasurably greater resources."

Every time I say that they will say "That's the first time anybody has said to us that we ever did or contributed anything at all." Too often they are made to feel that it isn't a question of give and take but that it is expected to be our giving and their taking continuously.

I feel impelled to say this to you at this special time because I do feel that there is a revulsion in this country as to the amount which we have given or may give to other countries in this whole management and industrial field without an adequate recognition that we are repaying debts. If there is a balance, we probably will be richly repaid as we go on into the future.

So much, then, for stressing the human element and the give and take, except to mention one or two new projects which I think are rather interesting.

I happened today to hear one of our own group on the West Coast who is a part of the Dynamics group who are studying the give-and-take from the dynamics viewpoint—this is the group that started in Maine and is now branching out here—others of our group are exploring into the field of dramatizations as you well know. Sometime they overstress, I think, the amount you can get out of dramatizations. None of us who is not a trained psychiatrist can expect to get from dramatizations what such a person can get. We have only to go to the Menninger Clinic in Topeka or anywhere else where they are putting on this sort of thing from the psychiatric standpoint to know that we are mere amateurs in that field.

But trying to make the adaptation, trying to get out of our group what we can by the kinds of dramatization which it is appropriate for us to do—that's very profitable. . . .

The newest phraseology of this field seems to be the Art of Communication. Now that simply means how to try to help people to free their own natural kindly impulses, if they have them, or to transform any other kind they might have into kindly impulses, if possible; and then to let other people know by their speaking, by their actions, by their listening, by whatever else they do that they feel warm, friendly, interested and cooperative. We have some pioneer courses in this going on in New York—one of the course titles is "The Arts of Communication," and it's something like a get-around-the-table affair with somebody experienced in this sitting as a panel chairman to bring the various factors of successful give-and-take into the picture. I am interested in it because it seems to have taken hold.

Somehow we seem to have to have not only a new slant, but a new terminology to put onto a new project when it is launched. That has been well known in the educational field. If you go to summer session, the one thing you are expected to bring back is some terminology that nobody has ever heard before, both to astonish the natives and to bear witness that you really have been to summer session. If it is a completely new phrase that nobody has heard, that is good; but if you can take a phrase that we all understand and put a completely new meaning in it, that is wonderful. "Climate of work" is an illustration; when it was preached upon in all of the teachers' colleges one summer, everybody went home saying "Climate of Work." You defined everything you ever knew about climate and you found that none of your definitions fitted, and by that time they were four sentences aheead so you said, "How wonderful it must be to go to summer session!"

Well this has now spread into our own field: new terminology to show that you have been in some kind of a new set-up. We may laugh at it, but I think it is a good thing because we get a certain impact in these new things.

We are putting more and more emphasis on teamwork. I am not going into that tonight for it's too long and it's too ramified. I just want to bring out two things about teamwork. You remember during the Elton Mayo wonderful experiments where they placed selected women in a room to test lighting, and you remember that they put on more light and production went up, and still more light made production go up; and then they began taking it away and production still went up. And the research men said, "What under the sun is this?" and somebody said, "It looks as if lighting had nothing to do with it."

Then a more intelligent one (I have always suspected that was Dr. Mayo himself) said "No, it does not show that. It shows we have some other variables in there that we do not know about, and they are probably so effective that the one we are studying has had no chance to function." And that was the truth. Three things were functioning there: one was the fact that these ladies were enchanted to have been specially selected; and second was the fact that they were enchanted to have been told that they might talk all they pleased about what they thought about things to each other, to their supervisors, and everybody else; the third was something that probably not even they knew and that was, fortunately, they had developed a very nice team spirit. They found that out when they tried to take some of them away and they protested.

And when they tried to substitute and add some others then again the group said, "We like our group just the way it is." Those things, I think, are things we must keep our eyes on as we are doing more and more in teamwork.

We in Industrial Engineering are teaming up more and more with other people. We are working with Business Administration people very closely indeed; we are working with Engineers of all sorts; we are working day in and day out right on the job with Psychologists, Physiologists; we are going to have Psychiatrists and Methods Measuring people. There are all people in widely diversified districts who are going to have to come together to solve these problems. And we've just got to remember as we go ahead that whether your team happened to be a team of nice young girls selected to work together in a little room in a big factory to try out a problem of lighting, or whether you have a problem important enough (as you do on some of these matters) that you have top flight people on a campus or a series of campuses, all over the country from widely different disciplines, the team will have the same problems of being a good team as they would in a very simple situation.

I think we should have tremendous concern in this problem of integrating loyalties. I do not know much about this. I am just exploring in it, but it seems to me that, when we look at the future of Industrial Engineering, teamwork and this matter of integrating loyalties are perhaps our most challenging problems. Look at the loyalties the average American has to integrate. You know that if there is friction you won't get anywhere; yet if there is lack of integration you will have friction. If you can have integration and serenity you can go far.

First of all, you have loyalty to yourself. I had that brought home to me in a very simple home situation. I was talking to a small daughter some years ago and I said, "I want you to do something," and she said, "I can't." And I said, "Why can't you?" And she said, "Because I promised." And I said, "Well, a promise is a very serious thing. Do you mind telling me whom you promised?" And she said very defiantly, "I promised myself."

Well, I thought about that for a while. At first I thought, what an easy way to get out of it! And then I started to think. "That child means that. She's defiant about it." So I said, "I think a promise to yourself is a very serious thing. Did you really think about it? Did you promise yourself seriously?" And she said, "Yes, I did. I promised myself very seriously." So I said, "Then I don't think I should ask you to break that promise; not unless I have arguments that will show that you shouldn't have made that promise in the beginning and I don't think I have."

I have thought increasingly that perhaps we have understressed this matter of integrating yourself. When you promise yourself you really agree with yourself that that's the thing to do.

Then you have loyalty to your family, to your school, college, your church, your community and your state, your nation, and now the United Nations; if you are in industry, to management, to your group, to your craft. It is a tremendous job to integrate these loyalties, but I think until they are integrated and until we have our teamwork set up in such a way we can depend upon it, you and I can use neither our techniques nor our fine human relations. That's the challenge I bring to us all. Let's try to meet it together.

ENGINEERING IN THE FABRICATION INDUSTRIES

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Operations Analysis

A technique which is gaining stature in engineering is entitled operations analysis. Briefly, a particular operation, say the production of a commodity unit, may be studied experimentally. An independent variable is changed and the effect on the dependent variables observed. Through the application of the appropriate scientific methods (such as factor analysis, the calculus of variations), the relationship of a change of each independent variable on each of the more important dependent variables can be established.

The application of operations analysis to problems concerned with providing increased output, plant expansion, maintenance and quality control, will result in more economical and rational solutions.

Design

Little has been said about the design of tools, dies, jigs, and fixtures. As the properties of materials become known, predictions of the work of plastic deformation and fatigue life will be possible. Again, if the energies required in the separation processes (cutting, sawing, polishing, etc.) are known in terms of the properties of materials, progress in design will result and production rates and costs will be influenced favorably.

Knowledge of the fatigue characteristics will support repair and service schedules, now based almost entirely on unformulated experience.

Often, the analytical procedures available are applied to only the design of a given commodity or production system. But the continuous application of the knowledge of properties of materials and of the several analytical procedures will result in more satisfactory repair and service schedules. Again, the flow of information relative to the commodity performance in its actual environment (which really are prototype tests) to the designer will greatly enrich his knowledge and will result in improved designs.

The reduction of wear and of corrosion, the reduction of the efforts of irradiation (fading, etc.) and other deteriorations may also be subjected to analytical treatment with beneficial effects. Plant conservation will be the direct result of these studies.

The foregoing statements yield a brief glimpse of contributions which the professional engineer can make to the industry. Engineers-in-training and young professional engineers may acquire the appropriate know-how through wisely conceived on-the-job training programs supplemented by off-the-job study.

DEVELOPING STANDARD DATA

(Continued from Page 15)

strictly necessary to develop meaningful standard data. Thus, there is no a priori reason why different workers could not introduce the same relationships among elements (or element groups) in organizing their work methods. On the basis of the test results, however, the likelihood of this is so remote that this alternative is of only theoretical interest.

To summarize the findings presented thus far, it is clear that operation elements defined according to current practice are quite often not independent of one another. Also, element groups can be defined so that independence is achieved in most cases. But having independent element groups does not of itself guarantee that standard data can be developed for predictive purposes. In fact, independence does not even imply that the element-group structures will be the same for different operations or even for different workers on the same operation.

To look into these questions, a third set of studies was made to check on the data previously tested for independence, using a number of multivariate likelihood ratio test procedures to make the analyses.[12] These test procedures, like Wilks' test of independence, are extremely complicated in theory and application; for that reason, only the results will be considered here.[13]

The principal findings were as follows: (1) the average times for elements as well as for element groups were not equivalent for different operators working on the same operation; (2) on the other hand, different operators did have an equivalent degree of variability in their element-group times (measured in terms of the time variances) in a few cases, but only when independence had previously been established. This finding strongly suggested that elements as currently defined, especially in man-controlled operations, will not usually be the same for different operators.

Considered together, these three sets of studies have extremely important implications regarding element standard data. First, they show that for all practical purposes man-controlled operations, at least, should be considered in terms of element groups rather than elements. Also, these element groups should be independent of one another, which means that they should be few and they should be large.

But even with element groups, the likelihood is quite small that two or more operators will have (statistically) equivalent

element-group times. In standard data work, however, it is not enough to find operation subdivisions that are common (in the sense of having equivalent time values) to all operators working on a single operation. These subdivisions must also be common to many different operations. This additional requirement makes the problem much more difficult, and it becomes increasingly difficult as more operations are compared.

When operations are being compared, an even more important limitation arises as a result of the grouping procedure introduced to achieve independence. This procedure combines the elements of a given operation into groups that only rarely will be found in other operations. Thus, the process of developing element standard data is a self-defeating process, especially with man-controlled operations. To meet the independence requirement, a small number of large element groups must be constructed. But this makes it almost impossible for different operations to have element groups that are even descriptively compartive.

But even if these extremely formidable difficulties could be overcome, a number of other questions have to be answered—if the objective is to predict the time required to perform a new operation. Thus, the new operation must have element groups which: (1) are descriptively comparable to those given in the standard tables, and (2) have the same averages and variance values. But the test results showed that likelihood of achieving this is extremely small. In fact, the only safe way to check this question is to subject the new operation to a series of test studies like those considered here, which would eliminate the need for making a prediction.

Assuming, just for the sake of argument, that all these difficulties could be overcome, there remain two major questions to be considered. The first is that the empirical value of a prediction, expressed in terms of its range of error, depends on the number of observations and on the variability of the observed data. The second is that the average times of elements and element groups decrease gradually as a result of improved methods and skills. This means that even though it were possible to answer every other question, a new set of standard data would have to be developed at periodic intervals by the same tedious and hazardous process as before.

Thus, element (more properly element-group) standard data is apparently an impossibility for all operations in which the workers exercise an appreciable influence on the work method and the work pace. The fact is that only for machine-controlled operations is there even a remote likelihood of developing standard data of this type.

In view of these findings, it is at once clear that **none** of the procedures currently recommended for developing element standard data is valid. Some of the specific shortcomings are that: (1) element standard data are often developed from observed data by using (statistically) invalid or inefficient measures of central tendency; (2) in many cases, so-called "abnormal" readings are discarded in advance on subjective grounds; (3) little or no attention is paid to the variability of production rates; (4) the question of whether relationships exist among elements is never taken into account and rarely even recognized.

In fact, almost all time-study texts implicitly assume that production rates are essentially constant; also, that each element is a completely independent unit, apparently because it has a unique verbal definition. These texts also seem to assume that the time required to perform a new operation can be estimated without error. In any event, sample sizes and variability values, which determine the range of predictive error, are never recorded on standard-data tables. Another essential difficulty is that all these texts deal with elements rather than element groups. As currently defined, however, most elements are not independent, to say nothing of their other deficiencies for predictive purposes.

A suplementary point of interest is that all current procedures require that the observed element data be rated subjectively. This practice is completely meaningless, however, unless the elements being rated are first established to be independent.

It also follows that the argument of consistency, upon which so much emphasis is placed in the literature, is completely unsubstantiated. In fact, the question of consistency does not even begin to have meaning unless and until: (1) it is established that the elements involved are indepedent; (2) the data are obtained and treated according to the test procedures discussed above. Quite aside from its lack of validity, arguing that standard data have the advantage of consistency implies that ordinary time studies, which would otherwise be used, give inconsistent results. This gives the argument a rather amusing footnote, since ordinary time studies are used to develop the basic standard data values. The over-all conclusion is that the results of current standard-data procedures are in most cases meaningless and in any case, have little or no predictive value.

These research studies also produced a number of other empirically important conclusions, only one of which can be touched on here. Many time-study texts and some leading labor unions take the position that only the elements directly affected by a change in method, material, or design are to be observed in restudying an operation.[14] The preceding material makes it clear, however, that the effect of such a change will generally not be confined to such elements. Instead, it must be expected that an operation change will produce a totally new element structure. The only completely reliable way to deal with the problem, then, is to determine the full effect of any given change, using the test procedures mentioned above.

Another group of research studies was made on motion standard-data and related problems. Both the test procedures and the results were essentially the same as they were in the element case. Accordingly, only the highlights will be presented here. In this case, time analyses were made from film records of certain laboratory operations, which meant that only a limited number of observations could be obtained on each. The timing instrument used was the so-called "wink-counter," which gives readings to the nearest two-thousandths of a minute when used in a camera field. It might be added that film studies of this type require so much "staging" that they can all be classified as laboratory studies, even when they are made in the factory.

One of the first findings obtained was that there is no justification for the rather common belief that the times required to perform so-called fundamental motions are constant within reasonable limits.[15] What actually happens is that constant readings are obtained only when the motions (or elements) are not much larger than the smallest unit of measurement. However, the readings cease to be constant when more sensitive measuring instruments are used. This means that inadequate measuring instruments are responsible for constant readings, not the basic motions or elements. To avoid such difficulties, (and also to achieve independent motions or elements), it seems advisable to adopt the following criterion: consider only motions or elements lasting at least five times as long as the smallest measurement unit.

As with elements, it was found that relationships often exist among fundamental motions as currently defined. However, independence can be achieved by combining these motions into motion groups which are smaller in number and larger in size. It was also found that the pattern of the relationships among the motions was different for different operators and changed after a (short) time even for the same operator. It seems safe to conclude from this evidence that these relationships would also vary from operation to operation and, more generally, from plant to plant.

These statistical results were corroborated by empirical evidence obtained by a detailed scrutiny of the films. This scrutiny showed that the motion structures of the operators differed greatly; also, the motions were performed in groups rather than as isolated units. This finding suggested that workers develop their motion structures as a whole rather than as a sum of separate and distinct motions.

It was discovered also that each worker's motion structure can be broken down into two distinct components. The first can be defined as the expected, relatively constant, and usual motion pattern, including a set of relatively fixed relationships among the motions. When a special situation arises, however, such as difficulty in engaging moving parts, the worker uses another motion pattern. This can be defined as the unexpected, varying, and occasional motion pattern, in which the relationships among motions are also changed. The nature of the occasional motion pattern depends on the nature of the situation encountered and on the worker's adjustment to it.

The test results showed further that for all practical purposes meaningful motion standard data can be developed only

from operations divided into a small number of large and independent motion groups. But even for independent motion groups, the likelihood of obtaining equivalent motion structures (in terms of average and variance values) for different operators is remote, especially when the number of operators being compared becomes relatively large. The test results also strongly suggested that it will be almost impossible to find descriptively comparable motion groups even in almost identical operations. Thus, very few operations will have motion groups that can even be compared, to say nothing of having equivalent statistical properties.

Even then, it would not be enough for established operations to have comparable motion groups with equivalent average and variance values. The new operations for which the predictions are intended must have comparable motion groups with the same average and variance values. These facts, however, can safely be determined only by obtaining and analyzing data from the new operations—a procedure that would make predictions unnecessary.

Sample sizes and variability values must also be such that the predictions will be empirically useful, i. e., their ranges of error will not exceed predetermined limits. It will be extremely difficult to meet the requirement in view of the limited sample taken in the usual motion study.

The likelihood of overcoming all these difficulties is even smaller for motions than it is for elements; the reason is that motions are influenced by the operator to a much greater degree than are elements. This finding also points up the fact that motion structures will not remain constant for very long. A new set of standard data would have to be developed, then, at relatively frequent intervals, assuming, of course, that all the other difficulties can be overcome.

Accordingly, the likelihood of developing meaningful motion (more properly motion-group) standard data is even more remote than it is for elements. In any event, it will be impossible to obtain motion standard data that can be used in all industries or even throughout one industry. This puts the problem of developing motion standard data up to the individual plant. The cost of making the required film studies under these circumstances would appear to be prohibitive, especially since the prospect of success is so meager.

The preceding material also makes it clear that all sets of motion standard data claiming general applicability—and almost all of them do—are invalid. The reason is simple and direct: they just do not apply to the motions considered in these research studies. In fact, probably it is precisely because different motions are used in different types of operation that the published sets of motion data differ so much from one another. This fact alone, as Gomberg correctly warns, is sufficient to raise a serious doubt about their validity.[16]

Quite aside from this, current motion standard-data procedures have all the weaknesses of element standard-data procedures. For example, nowhere is it acknowledged that fundamental motions are likely to be correlated or that there is a need to develop independent motion groups. The result is that every set of motion standard-data currently available is completely unacceptable for predictive purposes.

The research studies also led to supplementary findings concerning two basic notions related to the standard-data notion. Thus, the generally accepted notion that there is only a limited number of fundamental motions (between 15 and 25 are usually considered) is directly related to (and probably responsible for) the equally accepted notion that motion standard data could be developed for universal application.

The evidence obtained in these studies, however, showed that a limited number of definitions cannot possibly apply to all the motions encountered in industrial operations. Some writers, such as Gillespie and Fairchild, have attempted to solve this problem by developing more comprehensive definitions.[17] However, the motion patterns of different workers will differ in an almost infinite variety of ways. No matter how carefully they are made, then, descriptive definitions will never be completely satisfactory for making estimates and predictions. To identify a motion uniquely, it is also necessary to state its chief statistical properties by recording its average and variance values.

The research studies also showed that the "one best way" notion has the same shortcomings as the standard-data notion. This is only natural, since the standard-data notion represents an attempt to give physical meaning to the "one best way" notion. Thus, rearranging or revising element or motion structures, as the "one best way" notion requires, will produce an entirely new element or motion structure with unpredictable statistical properties. Another basic shortcoming common to both these notions is that little or no attention is paid to the quesion of variability in performance.

Editor's note: There was considerable reaction to Dr. Abruzzi's talk at the close of Friday's Session in Berkeley. In response to this reaction, Mr. Douglas Watson of McKinsey & Company, San Francisco, prepared the following questions which were answered by Dr. Abruzzi at the beginning of the Saturday morning session.

Question: From the practitioner's viewpoint, how can reasonable tolerances of precision and predictability be defined? **Dr. Abruzzi:** The degree of precision and predictability (in terms of the range of estimating error) must be determined by the economic and other empirical requirements of the plant. Precise estimates may be required, for example, when time study results are to be used to make important decisions about production costs, etc. For most cases of this kind, 5 per cent seems to be a reasonable choice for the maximum range of estimating error.

Question: In view of your earlier comments, are we to conclude that you doubt the worth of incentive-wage plans for increasing production effectiveness? **Dr. Abruzzi:** There is no doubt that incentive-wage plans generally increase both production effectiveness and worker earnings, sometimes substantially. However, it is also important to realize that such plans have only a limited and temporary incentive value. Thus, the incentive may raise the average output by, say, 25 per cent and average earnings by a corresponding amount. But once the full incentive effect has been realized, no further substantial increases take place and both production and earnings become stabilized at a new level, which workers and management come to consider the expected normal level.

This means that industrial engineers should seriously consider the use of non-financial incentive plans in addition to incentive-wage plans. Such plans are much more likely to be continuous in their incentive effect, especially when they bring out the worker's interest in his work, workplace, and product. It is only by creating such a continuius incentive environment that industrial engineers can obtain truly optimum production effectiveness.

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[1]The full details of the material considered in this paper are contained in A. Abruzzi, "**Work Measurement: New principles and Procedures,**" Columbia University Press, 1952. This work also considers in detail all the other major problems involved in this field, such as process standardization and the estimation of production rates and delays.

[2]Frederick W. Taylor, "**The Present State of the Art of Industrial Management,**" **Transactions, American Society of Mechanical Engineers,** XXXIV (1912), pp. 1199-1900.

[3]Phil Carroll, "**Time Study for Cost Control,**" 2nd Ed. McGraw-Hill, 1943, pp. 18-32.

[4]William Gomberg, "**Trade Union Analysis of Time Study,**" Science Research Associate, 1948, pp. 158-159.

[5]Marvin E. Mundel, "**Systematic Motion and Time Study,**" Prentice-Hall, 1947, pp. 178.

[6]See, for example, J. H. Quick, W. J. Shea, and R. E. Kohler, "**Motion-Time Standards,**" **Factory Management and Maintenance,** CIII, No. 5 (1945), pp. 97-108.

[7]See A. Abruzzi, op. cit., and R. M. Barnes, Industrial Engineering Survey, University of Iowa, College of Engineering, 1949. Industrial Engineering Report No. 101.

[8]R. F. Hoxie, "**Scientific Management and Labor,**" D. Appleton & Co., 1916, pp. 51-52.

[9]T. A. Ryan, "**Work and Effort,**" Ronald Press, pp. 232-235 and E. E. Ghiselli and C. W. Brown, "**Personnel and Industrial Psychology,**" McGraw-Hill, 1948, pp. 268-270.

[10]R. M. Barnes and Marvin Mundel, "**A Study in Simultaneous Hand Motions,**" University of Iowa, 1939. Studies in Engineering, Bulletin 17.

[11]A. Abruzzi, op. cit. This work also describes in detail the operations, the plants, and the other empirical characteristics of the studies made.

[12]The theoretical aspects of these test procedures are discussed in Wilks, "**Certain Generalizations in the Analysis of Variance,**" Biometrika, XXIV (1932), pp. 471-494.

[13]The full details can be found in A. Abruzzi, op. cit.

[14]See, for example, "**The UAW-CIO Looks at Time Study,**" The United Automobile, Aircraft, and Agricultural Implements Workers of America, July, 1947, pp. 30.

[15]See, for example, A. B. Segur, "**Motion Time Analysis,**" Proceedings of the Time and Motion Study Clinic, Industrial Management Society, Nov., 1948, pp. 40-48.

[16]W. Gomberg, op. cit., pp. 156, 159-160.

[17]James Gillespie, "**Dynamic Motion and Ttime Study,**" Paul Elek, Ltd., 1947, and Mildred Fairchild, "**Skill and Specialization I.**" **Personal Journal,** IX (1930), pp. 28-71.

NEW SELECTION

(Continued from Page 10)

self, say in an investigating and research manner.

The principles underlying the technique distinguish it from those upon which psychological testing is based and the methods can easily be demonstrated. Parallel assessments have been made together with industrial psychologists and although there is no possibility of merging the techniques the joint research towards the common aim has helped to substantiate the Laban Lawrence assessment.

The advantages of a form of selection assessment which occupies the candidate for less than half an hour and needs little pre-arrangement, yet has provided results upon which action can be confidently taken, may seem almost incredible at first hearing. Its basis of scientific discovery into the elements of human effort will command the technique to all concerned with personnel problems. Its simple effectiveness makes it much in demand commercially.

Mr. Lamb is presently in the United States on a speaking tour, and will remain until December 31, 1952. At the time of this writing, he has some open dates. Any persons desiring to arrange for Mr. Lamb to discuss the subject treated in this article are requested to write to Mr. M. A. Payne, President, A.I.I.E., 40 West Gay Street, Columbus 15, Ohio.

WORK MEASUREMENT

(Continued from Page 11)

eration of an alternate hypothesis.

A second factor must also be considered. The tests employed by the author require the assumption of a joint normal distribution of the *variates*, if used as a test for the hypothesis of independence. (This is automatically satisfied if the variates are independent and have individual normal distributions.) To justify the assumption the author employs a rather loose definition of the central limit theorem, which, as a basis for assuming normality, is regarded with considerable skepticism in contemporary scientific literature (see section 5.22, Volume 1 of Kendall's "The Advanced Theory of Statistics"). But, however reasonable the argument may seem, it does not cover the actual situation. As noted previously, the *variates* in this instance were *not* element times but *observations* of element times. And where the observations for an element exhibit only the two values, .01 and .02, it is quite apparent that this distribution is *not* normal, whatever may be the distribution of the quantity being measured. Hence, the author's assumption of normal distributions of the variates seems hardly to be justified.

In view of the foregoing the author does not appear to be on firm ground in construing his analysis as a test of independence of element times. We think it would be more precisely described as a simultaneous test of normality *and* the hypothesis of independence among observations of element times. In brief, then, a statistically significant result would be subject to the following interpretations: a) the assumptions do not hold, b) the assumptions do hold, and the observations are not independent, c) there is both a failure of the assumptions and a lack of independence among observations. To (b) and (c) are added the sub-alternatives that the inferred lack of independence of observations is due to: 1) correlations introduced by the process of observation, 2) correlations existing among the element times, or 3) a combination of these two. Since the analysis does not provide an objective basis for choosing among these alternatives, there would appear to have been a crucial sacrifice of precision. Our criticism here is concerned primarily with the author's failure to state this difficulty in the analysis and to present and discuss the alternative conclusions which might result from it. While he himself chooses alternates (b,2) the conclusions cannot be considered the product of strict scientific inference. Again, this does not prove his conclusions wrong, but merely doubts their "conclusiveness."

While the function of a review is critical appraisal, it should be emphasized that the foregoing comments do not deprecate the value of the author's experimental work. They are an observation, rather, of his failure to adequately note certain sacrifices of precision, to analyse their effects, and to explain their justification in exploratory research.

To judge this work according to its qualifications as a rigorous scientific analysis of precisely stated hypotheses would be unfair in view of the present state of the field. But judged as exploratory research this is one of the important contributions in the field of time study. Judged as a practical manual, we would also say that the analytical techniques will certainly produce information of considerable value in solving practical problems, if they are used by persons who thoroughly understand them. We would consider as somewhat exaggerated, however, the claims of the Columbia University Press (on the book's jacket) that it "presents a complete methodology for handling the problems of work measurement . . . the means for evaluating all aspects of work performance on an objective basis." There must be a great deal more exploratory research, a great deal of development effort, and more extensive training of Industrial Engineers in the fundamentals on which these new techniques are based before that hope may become a substantial reality.

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INCENTIVES IN A FOUNDRY

(Continued from Page 5)

Allowances for fatigue, personal time, scrap, miscellaneous minor delays, interferences, etc., are also applied.

All performance standards or standard time values for both direct and indirect work are established from detailed time study analysis. On repetitive operations a whole group of sizes of products are time studied and standard elemental time values are built up from these studies and charted. By using these charted times, we build up standard time values for a variety of closely related operations. This minimizes errors, improves consistency and increases total plant incentive coverage.

A permanent record (job specification) is made of the exact method, motion sequence, tools, equipment, fixtures, size and type of product, quality, finish, dimensions, weight of material or parts handled, distance moved, length and depth of cut, feeds, speeds, size flask, type patterns, corebox, drawing number, etc., relative to the job, and the standard time for performing the work. Copies of this record are given to the union, foreman, time and production checker and works manager.

Production standards must be properly maintained so that extra earnings above base pay will always be in direct ratio to performance above standard. Our incentive plan provides for the changing of production and incentive standards when there has been a change in the method, equipment, finish, material, etc., which will affect the amount of time and work required per unit, or the total expected output, but the change must be legitimate if good industrial relations are to be maintained. If an error in judgment is made by the time study man which results in a "loose" standard time value, it is not changed (unless by mutual agreement between the union and the company), but rather is left as a monument to good faith.

When operators make suggestions that effect a savings on an operation, they are paid a cash award and the standard time value is changed to correspond with the work required. This award is based on the savings involved.

The number of good pieces produced is recorded by a roving time checker who counts and records production, down - time, unmeasured - time, hours worked, etc. Incentive workers are paid for down-time or delays over which they have no control at their guaranteed base rate. Good time and production checking is important from the standpoint of good industrial relations and proper maintenance of the plan.

The earnings and performance of each operator is computed and posted on the bulletin board daily in his department. This is for the operator and its chief purpose is to let him know his earnings and performance for the preceding day. He is able to check each day while the work done is still fresh in his mind to see if his pay and performance have been correctly computed. He may also compare his performance with those of other operators.

The posting sheet allows the foreman to pick out those operators who are sub-normal. Frequently, these operators can be assigned to other operations to which they are better suited, thus accomplishing the double service of salvaging a job for them and eliminating a labor loss for the company. Lost time expenses such as waiting for work, breakdowns, rework, excess scrap, process allowance, etc., can be quickly spotted and measures can be taken to correct these losses whenever possible.

We do not consider our incentive plan a cure-all or a substitute for good supervision and management; it is not even a primary remedy for industrial ills, but a phase of control effective only after such measures as methods and process studies, motion analysis, job standardization and job evaluation have been carried out. Wage incentive is only the oil that makes the control machinery work.

The incentive plan releases forces acting on two of the most potent factors in labor relations—wages and effort expended. Therefore, in establishing the plan, all available scientific and engineering ability was used, combined with a sympathetic attitude toward the human relations involved. Many worthwhile suggestions were made by the foremen and operators themselves.

Our wage incentive plan has been a constructive force for increasing production. It also has increased employees' earnings by 25 to 40 per cent and has reduced costs at the same time. Before the application of incentive to plant maintenance employees, we operated our machine shop and foundry maintenance crews six days per week. After applying it to these operations we eliminated the overtime and are actually getting better maintenance in a five day week than we were formerly getting in a six day week with the same maintenance crew. Production in the foundry is also better because we have fewer delays. As a result of standardizations and improving our patterns and coreboxes, we have reduced the cost of cleaning and chipping all of our pipe fittings by about 60 per cent. It is important that any incentive plan be given attention by top management. Nothing is more important to a wage incentive plan than its maintenance—the same is true of hourly base rates.

NUMERICAL METHODS

(Continued from Page 7)

tions with n initial conditions. These methods depend on recurrence relations which are usually set up by means of series expansions. In addition certain special cases are given attention where the solutions are not dependent on Taylor series expansions.

The techniques of Chapter IV are designed for second and higher order equations since these evolve from boundary value problems. Due to difficulties in solving odd-order equations, these are generally transformed to even order equations by integration or differentation. In the treatment of derivatives appearing in the equations and/or in boundary conditions, finite differences are again employed where possible.

The final chapter considers partial differential equations which lead to partial difference equations by applying essentially the methods considered earlier. Certain methods of double integration are also treated. The Laplacian equation as applied to two-dimensions physical problems such as steady state heat, electromagnetic and elasticity problems is solved by numerical methods. Likewise the Poisson equation relating to electricity, magnetism, and elasticity is solved. In addition, other problems on elastic and plastic torsion are treated. The problem of determining the compressive force required to buckle a square plate and that of membrane vibration illustrate other techniques. Finally, methods relating to the Laplacian operator in skew, polar, and rectangular coordinates are given.

In conclusion, this book is not light reading material for the casual engineer or industrialist. However, those who require the type assistance and information which it offers will find it interesting, suggestive, and useful.

Have You Seen This?

FUNCTIONS AND BASES OF TIME STANDARDS

A new service by A.I.I.E. to its members, and others interested in the field, is inaugurated with the publication of a 400 page technical report, "Functions and Bases of Time Standards." Authored by Dr. Harold O. Davidson, Ass't Prof. of Industrial Engineering at The Ohio State University, the report is offered in a limited edition of 200, at $8 per copy. Works of this type which are too technical or specialized to interest text-book publishers have generally been available only as loan copies from university libraries or as photostats or microfilms at prohibitive cost to the individual engineer. This cost of this report is unusually low considering the small number of copies over which fixed publication costs must be spread. Such profits as may be realized from the distribution of this report will go into an A.I.I.E. fund ear-marked for the support of future technical publications. Groundwork for the publication of this work by A.I.I.E. was laid by K. Theodore Korn, of the Cleveland Chapter, and the Research Committee on Synthetic Time Systems of which he was Chairman.

Dr. Davidson's analysis of standard-data systems will alone be worth the cost of the report to many readers. In addition to discussing fundamental assumptions and limitations of the standard-data method, he presents a statistical analysis which reveals great discrepancies among different systems of data in present use. His analytical review of early time study development does much to place the work of Taylor and others in proper perspective with the field as it is today. While the author accords with some of Gomberg's analyses, he presents a fundamental objection to the latter's concept of a scientific time study system. Many other topics are treated in this 400 page research study.

The author's formal training included work at Northwestern University and Georgia Institute of Technology, leading to degrees in both Mechanical and Industrial Engineering. In earning the Ph.D. degree from the Ohio State University he took additional work in the field of Industrial Psychology. From this formal background he brings to his analysis something of the scientist's critical objectivity.

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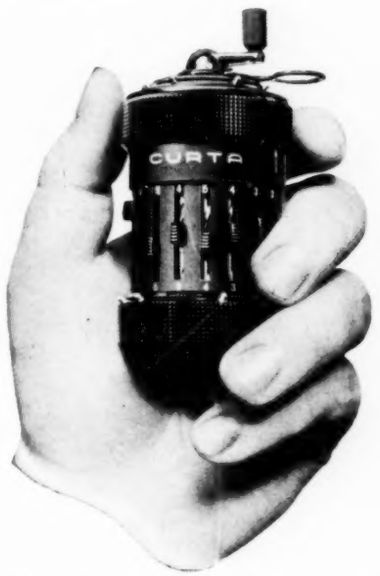

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